PROCEEDINGS OF

SRM 2002: SAVANNA/WOODLAND SYMPOSIUM

Edited by

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PREFACE

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What's a savanna look like? How do I tell savanna from woodland or forest or from old field or woody invaded pasturage? Where's the line that makes a piece of land a savanna or woodland or something else?

Natural landscapes are a continuum of plant and animal communities grading from one to another. Altered landscapes generally have their land cover compartmentalized into units by roads, fences, or trails. As land managers, we are trained to manage timber in stands, crops in fields, and pasture in grazing units. Though we attempt to manage the entire forest or the entire land holding, we still think as we have been trained, in units. Delineating units allows us to organize our management alternatives into workable groups. In altered landscapes, this approach works quite effectively. However, when trying to decide where natural communities start and stop, we are perplexed by the variety of different criteria used to define the different communities. When faced with communities that are themselves transitional communities between the major land covers of prairie and forest, the task becomes even more perplexing.

To that end, this Savanna/Woodland Symposium was developed to aid land managers in understanding the components that constitute that part of the natural continuum called savanna or woodland, the value of this vanishing land cover type, and how to best restore this habitat to the landscape.

From an idea conceived by Ken McCarty, Missouri Department of Natural Resources, this symposium presented the work and thoughts of 12 people with extensive backgrounds in savanna and woodland communities and their management. The goal of this symposium was to provide a primer for land managers as they incorporate savanna and woodland management into their overall management programs.

This symposium does not provide the final word on savanna and woodland, but rather a basic background on these natural communities that will allow you, as a land manager or consultant, to better manage savanna and woodland community types. Your long term expertise in managing these land covers will increase as you learn by doing. Share the information and insights you gather so that we may all continue to learn.

WHAT IS A SAVANNA?

Dr. Gerould Wilhelm
Conservation Design Forum, 375 West First Street
Elmhurst, IL 60126

Introduction by Ken McCarty:

Dr. Wilhelm is a long-time student of the natural history and ecology of savannas and woodlands. He is a well recognized authority on native flora, and co-author of the definitive text, "Plants of the Chicago Region". Many Midwestern managers will recognize him as the principle developer of the Floristic Quality Assessment methodology, a quantitative means of evaluating the natural quality of plant communities. He recently served as the Midwest's board representative to the Society of Ecological Restoration.

Dr. Gerould Wilhelm:

The characteristics and limitations of language in the formulation of thoughts seem to me to be a powerfully important aspect in understanding the nature of our landscapes. One of the more important aspects of the use of language, particularly in trying to understand living landscapes, is how oral and written languages differ in their impact on communication. We users of a written language are constantly driven to arrange limits or borders on almost all things, because written words have limits or borders, with mandated hard and fast definitions. Consequently, our understanding of natural systems is constituted by the compilation of piles of facts and figures, models with dimensions, and places with edges. Understandings borne of unwritten languages can make it easier to see the circles or cycles of nature, easier to comprehend the infinities and paradoxes. Indeed, users of oral languages can be confounded by lines and borders, and tend to see them as interruptive of understanding. Nature itself is poorly described by the reduction of its essential aspects and interlinks to lines and borders.

Bearing in mind that English and German are in the same language class, consider that there were no fewer than 26 language classes in North American prior to settlement; Shawnee, Illinois, Miami, Wampanoag, Ottawa, Ojibwe, and Potawatomie, for example, were among many other languages in one class. The diverse manifestations of arboreal development in North America were accommodated nomenclaturally, if you will, by a great diversity of languages. We are attempting to apply the word *Savanna* consistently across the region and the country; we even imagine that such an attempt is within the realm of science.

Having said that, I being a user of a written language, American English, will attempt to visualize the Midwestern timbered landscape from the perspective of both oral and written languages.

The American Heritage Dictionary of the English Language defines *savanna*:

Savanna: “A flat, treeless grassland of tropical or subtropic regions.”

Merriam Webster’s Collegiate Dictionary:

Savanna: “1: treeless plain esp. in Florida 2: a tropical or subtropical grassland containing scattered trees and drought-resistant undergrowth”

The word savanna, originally something like *zavana*, comes to us by way of Spanish, from an Arawakan speaking people, the Taino, from the West Indies, who evidently used a word that sounded like *zabana* to the Spanish. Arawakan is a broad linguistic class spoken by many native peoples of South America. We also get the word *tobacco* from the Arawakan speaking peoples.

It seems like a strange etymology that a word from a language not even spoken in North America would become one of such contention in our attempt to define the timbered terrains of Midwestern North America. It is even stranger that the original meaning of the word was to describe a place that had neither trees nor hills.

Today, the word *savanna*, sometimes spelled *savannah*, has become the default word to categorize those places that seemed different from places like “woods” and “forest”, to which English words already had been applied. Also, words of German extraction, such as *der Wald* or *das Wainland* or *die Waldung* may have seemed too closely translatable to “woods” or “forest”, places for which 18th and 19th century people of the Old World already had too neat a concept to include the kind of woody lands they encountered in prairie America.

The word “prairie” comes to us originally from the Latin *pratum, prati*, meaning plain, and then “prairie” by way of the French. We could just as easily have adopted the French words for our prairie woodlands, like *la foret*, or even *la bois*, or perhaps the Gallic derivative of *silva, silvae*. Then of course, there is Spanish. We certainly have adopted the word *rio* for places with rivers in them. Why not *el bosque*, their word for forest.

Well, one could go on and on with this *ad nauseam*, of course, and at a rational level it would not really matter except that we have now attempted to attach a “scientific” meaning to a single word that is supposed to apply to all timbered communities that do not evoke the image of an Old World temperate forest. So, it is the view of some that a savanna is a wooded plant community that has less than 30% tree canopy cover. Others say 40%, some others 50%, and so on. Given the acceptance of any particular percentage, what would be called all the other wooded assemblages? Would they be *forest*? Even scientists would have trouble defaulting everything else to “forest” or even among words such as “forest”, “open oak woodlands”, or “barrens”, which, to be consistent, must have their own scientific limits.

I will not get into the theory that savannas are just Eastern deciduous forest aspirants, merely in a “successional” phase. Indeed, the idea that oak and hickory woodlands of the Midwest and the interior highlands are merely arrested stages on their way to the vegetation maximum, Beach-Maple Forest Primeval, ignores biome-level abiotic factors and vegetational history. Why could we not just as easily say that Eastern deciduous forests are senescent phases of Midwestern forests? Either view would be reflective of the regional or dogma centric tendencies of western scientific thinking. The fact the American English evolved form Plymouth and Charleston, westward, rather than from Kentucky City eastward, may be a factor.

In practice, we are most comfortable applying the word forest only to the kinds of woods early 20th century ecologists associated with the eastern United States and the Appalachians. In our area, such woods are best expressed by those closed canopy maple and beech forests that have gone unburned since before ecology became a science, or at least in the memory of anyone living or since the time of early 20th century ecologists. Actually, we have somewhat similar problems in attempting to classify peatlands and certain minerotrophic wetlands as either “bog” or “fen”. Too often it seems that people are led astray by their language into thinking the world is as simplistic as bog or fen, marsh or swamp, woods or forest, black or white. The world is not easily described in black and white, but actually exists in a full spectrum of color, even colors that our eyes cannot see. This business of plant community classification is far more a matter of linguistics than of science.

I thought for a while that maybe the “savanna” question had been resolved when Steve Packard announced several years ago at the Savanna Conference in Bloomington, Illinois, that savannas are those places that are characterized by “trees with big nuts”. In point of fact, it is a definition that would work well enough for me, but, alas, it does not sound “scientific”.

It would seem that written languages work well for the prosaic, for describing bridges and airplanes, but they disintegrate in effectiveness according to the degree an idea includes love, feeling, even history, and the warp and weft of the biotic and abiotic manifestations of a living earth. Hence the evolution of poetry, music, and art. The extent to which the realization that definitions begin to fail is the extent to which one is aware of the subtle differences each acre of earth imparts to its indigenous plants, animals, and even long-term human cultures. These subtle differences are often attributed by indigenous peoples as embodying a local guardian spirit or numen. So, the problem for those of us who are trying to discern the nature of our native vegetation lies in how we can blend disciplined, even dispassionate, assessments of information and data with the apparently numinous aspects of particular places.

I should probably insert here an observation on the nature of science in its contemporary mode as a tool for understanding nature. “Good science”, as it is commonly called today, by its very nature, is poorly constituted to integrate unrepeatable observations, however accurate, anecdotes, and even common sense. Consequently, that kind of science can inform us only of facts that can be re-measured. It cannot inform us about the immeasurable singularities so ubiquitous and interlinked in nature. At the same time, understandings borne largely out of intuition or feelings are just as limited. They are informative only in proportion to the amount of repeatable observation integrated into the formation of the intuitions or feelings. Genuine knowledge and wisdom seem most substantially constituted from a balance of emphasis on both the mythos *and* the logos.

Certainly, in any attempt to understand our Midwestern timbered lands, we must begin with the sure knowledge that the words of our language are limited, and that it is impractical either to invent an infinite number of them or to make their use so broad as to have little meaning. AS we realize this, we are chastened by dogmatic declarations as to the applications of such words as savanna or forest and are accordingly comfortable in our ability to communicate with one another on a general level. Rather than being enslaved to the number one good definition of “savanna”, we can free ourselves to examine the arboreal manifestations of a particular place.

At the end of the day, however, we need to back off a step and appreciate that, with respect to the so-called savanna, we are focusing on a biological aspect of the landscape that is both large and easily identified: trees. In fact, the size and conspicuousness of trees belies the fact that there may be and, probably are, other perhaps less romantic biological aspects that are as informative, or even more so, about Midwestern timbered lands than trees, namely the grasses and sedges, lichens, kinds of beetles, or kinds of birds.

Of course, the big question for most of us is: What is the optimum vegetational development likely to be in the place that I am managing? Which assemblages of plants and animals sustained the highest native biodiversity and supported local *natural* processes? And: What is natural?

I had an opportunity a couple of years ago to visit Walpole Island, Ontario, which the native people there call *Mnisenh*; it is also called *Pkejwenong* (place where the waters divide). *Pkejwenong* is a large delta island in the St. Clair River, whereupon there resides the nishnaabeg of three remnant tribes: *Jibwe* (Ojibwa), *Daawaa* (Ottawa), and *Boodewaadmii* (Potawatomie). All of these people speak languages of the Algonquian class. Other tribes whose languages are of the Algonquian family include the Shawnee, Miami, Illinois, Peoria, Piankashaw, Sauk, Mesquakie, Kickapoo, Menominee, and Cree. For thousands of years the languages spoken in the Midwest were probably largely Algonquian in their sounds. Words that sound something like Mississippi, Muskingum, Maumee, and Michigan: Tecumpse, Chaubne, Michiqueniqua, and Wehepehyerhesenwa. Notice that labial consonants are common; the lips touch. Listen to words derived from Iroquoian tongues: Onondaga, Ticonderoga, Huron, Oneida, and Cayuga. The lips do not move very often and rarely meet.

During that day on Pkejwenong, I was privileged to be able to speak with Reta Sands, a Jibwe woman, who one day, I am sure, will be a tribal elder. She speaks the Jibwe tongue, and knows many of the ancient stories and songs of her people. It is well documented that, Walpole Island contains perhaps the finest and largest lake plain “savannas” in the Midwest. The people of the Walpole Island have been firing it annually, as per tribal tradition, from time beyond mind. The treed places in the island are many and varied, with canopy covers that consist of singles trees per acre to closed canopy; certainly a dizzying array of “canopy closures.” In almost all instances, the floristic composition is amazingly rich, with readily apparent species that flower throughout the growing season. On a single field trip in August, I recorded 248 native species! Actually, more than 800 species of vascular plants, 97 considered rare in Ontario, are known from the island; a total of 146 species of birds have been recorded as breeding or potentially breeding there, 28 of which are considered rare in Ontario.

Listen to the ancient sounds of the Algonquian words Reta spoke when I asked her about this plant and that: mshkode-miizhmizh (Red Oak), hgaakmizh (Bur Oak), zhiigmewanzh (Red maple). These are the sounds that filled the air over our lands for thousands of years. Words like “prairie” and “savanna” suddenly sound kind of foreign and inappropriate. Their roots did not grow here.

In my view there are some key differences between words that are passed on to the next generation orally, and those that are passed on as written entities. I think there are two important differences. First, the very nature of the words, and second, the manner or context in which they are passed along.

With respect to the first difference, I am reminded on an anecdote from the life of Tecumpse, the great Kispokote leader of the Shawnee people. One of Tecumpsc’s younger brothers, Lowalowethica, later to become Tengskwetawa (Open Door – The Prophet), was fascinated by the books what white settlers were carrying down the Ohio River. Lowalowethica pointed out to Tecumpse that these white men could tell what another one said by simply looking at marks on paper. This interested Tecumpse a great deal, and may have been one reason he later befriended a literate white man named Galloway, who built his farm in the place where Tecumpse had grown up.

When Tecumpse showed his older brother, Chick(th)sika, these words, Chicksika was appalled! Already annoyed and concerned about these bewildering whites, Chicksika asked "How can you trap a word out of the air and make it always mean the same thing?" It has always been hard for whites to translate Indian discourse into written languages. It seems to come out poetically, what we might interpret as flowery and filled with metaphors. Spoken words were nuanced with timbre in the voice, facial expressions, and other animated coincident behavior. The strength or nature of the words in part were attached to the speaker and his reputation. Chicksika pointed out that one cannot look into the eyes of the writer to see if he had been listening to bad birds, and that anyone could read the words even if the elder knows they are not ready for them. To him, this explained why the White Man had such inexplicable, even dreadful behaviors with respect to the land and the Shawnee.

Written word, in contrast, must stand alone, without context other than the recorded circumscriptions of scholars of the language. In prosaic discourse, the word has a meaning that practitioners of written words attempt to replicate consistently with each iteration, in a sense to quantify them scientifically. Only poets, singers, and painters can escape the hide-bound limits of written discourse, while we ecologists feel compelled to define "savanna" quantitatively, once and for all, and preferably for all places.

Another difference between oral and written tradition is that in the oral tradition, the young ones learn words and ideas only from elders, when the elders think they are ready to understand. On the other hand, written words and ideas are available to anyone with a knowledge of phonics, irrespective of their cultural development or maturity, and commonly with little or no knowledge of the character or reputation of the writer.

Let us go back to Walpole Island, Pkejwenong. It soon occurred to me that Reta would have words that applied not only to individual plants, but to plant communities as well, so I decided to ask her: "What is your word for prairie?"

"Well, you must know that one of our words for fire is *ishkode*. Our word for the prairie is *mshkode,* which means: the burned over bare land." She moved her extended arm, palm down, in a flat arc before her.

Intrigued, and acutely aware of the current controversy over "what a savanna was", I pointed to the place where trees were, and asked, "What do you call that over there, where the trees are?"

"We call that *mtigwaaki*, our word for forest."

My initial reaction was one of disappointment. For here was an area dominated by a variety of trees, characterized by a forb-rich, graminoid ground cover, that burned annually, and she had seemed to announce that it was merely a "forest". I do not actually know what I had expected her to say. Maybe something that translated into "the burned place with trees that bear big nuts." It would have been more romantic and would have vindicated Steve Packard!

Slightly crestfallen, I queried her further, still deeply interested generally in the linguistic connection between people of long local inhabitancy and their land. At the end of the day, back in the heart of the town, behind some buildings, I noticed a small tract of unburned woodland, grown up underneath, dark-just like a contemporary Midwestern "forest". It looked so different from the rest of the island. Almost as an afterthought, I asked Reta, "What do you call that?" I feared she would reproach me for inattentiveness and reiterate merely that it was *mtgwaaki*.

Instead, her countenance changes; she shivered involuntarily. “Oh!” she said, becoming a little agitated. “That we call the *goodaakwak*! I learned that word from a song as a young girl. It means a very frightening place. But there is a word even more terrifying than *goodaakwak*, and that is *aakwaagwak*, which is the edge of the *goodaakwak*.” I later looked these words up in Richard Rhodes’ Eastern Ojibwa, Chippewa, Ottawa Dictionary, published in 1985. According to Rhodes, who incidentally consulted Reta extensively in the writing of his dictionary, *mshkode* means “prairie” and *mtigwaaki* means “forest”. Pretty straight forward. But, if I head her words accurately, *goodaakwak* and *aakwaagwak* were not treated by Rhodes, although he lists *aakwaadak* as meaning to be dangerous. Evidently, these are words that are generally not much in use in common parlance, coming to Reta only as she recollected childhood songs.

So what might they connote? *Good* – when attached to other words usually conveys the idea of being hooked or hung or caught. *Aakwaa* – is the root of words signifying danger. Together they could evoke the idea of being tripped up or caught up, or slowed down or hindered by dense undergrowth. Also, people who spend their days in *mshkode* and *mtigwaaki* have small pupils, accustomed to a lot of light, and great depth of field. Certainly they would be unable to see into the *goodaakwak*, where an enemy might lie hidden in ambush.

At all events, *goodaakwak* was a frightening place that one would approach with extreme caution. *Aakwaagwak* is not listed either, but *aakaa*, a very similar sound to me, means, according to Rhodes, “what a hell of a place”.

This has implications for an interpretation of *mtigwaaki*. It is a three-syllable sound that means not only forest, but, by corollary, a safe place, an open place where people can hunt and gather with success and security. What is important here for the contemporary student of Midwestern prairies and woodlands is that these communities probably represent Holocene-landscapes, tended by indigenous peoples, *nishnaabeg*, whose relationship with the land nurtured a great diversity of plants and animals and provided ready availability of clean water, medicine, herbs, and other resources necessary for their sustained inhabitancy.

Whatever one’s view on the apartheid between Nature and Man, it is becoming ever clearer to me that such a distinction is confounding western Man’s ability to see his role in the world and to understand and to comprehend the way the world, upon which he depends, works. Develop arcane, mathematically correct models of savanna and forest if you wish, if that is a goal unto itself. But if we wish to preserve and maintain the biotic and abiotic integrity and genetic diversity of the places with trees, then we must strive just as diligently to restore the Human cultural relationships with any specific landscape that has developed dependencies between the Human stewards of the earth and their charges. We must learn to fear *goodaakwa*, and grow to feel comfortable with and learn to nurture *mtigwaaki*. Our management feedback should be driven by the resurgence and sustainability of local native biodiversity, rather than a *priori* requirement of specific tree density and canopy cover per se. If our management of the local biota, at any particular place, enhances their inhabitancy, then that particular slope or acre will describe for us the appropriate conformation of trees themselves.

CLASSIFICATION AND CHARACTERIZATION OF SAVANNAS AND WOODLANDS IN MISSOURI

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ABSTRACT

The travel journals of early settlers and explorers eloquently unveil the splendor of beautiful savannas and open oak woodlands. The vast wealth of the biological riches our ancestors described are the envy of many a natural resource manager. Much of this tremendous biological wealth has vanished. Classifying and characterizing our biological heritage is at the foundation of carefully considered conservation planning, especially given limited resources and globally threatened ecosystems. As classification evolves, understanding exactly what savannas and woodlands are, how they work and what happened to this once-widespread natural community is critical for setting conservation and management objectives. In 1985, I authored "The Terrestrial Natural Communities of Missouri," which was published by the Missouri Natural Areas Committee (MONAC). This document described savannas and forests, but not woodlands. A technical classification subcommittee of MONAC revised the classification system, which was later adopted by MONAC in 2001. The presenter will describe and characterize Missouri's savanna and woodland natural communities in the context of structure, dominance, diversity, topography, quality, and relationship to fire behavior.

INTRODUCTION

The Missouri Natural Areas Committee and the Natural Heritage Program use the classification system to inventory, describe, nominate and manage natural areas, and collect natural features information from statewide inventories. Nearly 20 years has passed since adoption of the original classification system. In that time, managers and field inventory specialists have applied the system to restoring ecosystems and collecting additional data. The Missouri Resource Assessment Partnership has created numerous GIS layers on topographic relief, vegetation, geology, landform, and soils. Interpreting this data coupled with field inventory and ecosystem restoration has increased an understanding of the need for distinguishing and further defining forests and savannas. The technical classification subcommittee developed a prairie-forest continuum matrix chart (Table 1) to aid in describing and differentiating forest, woodland, savanna, and prairie.

TABLE 1:

The Upland Prairie-Forest Continuum

Current system	Forest		Savanna			Prairie
Attributes	Mesic Forests	Dry-mesic Forests	Dry-mesic Woodlands	Dry Woodlands and Flatwoods	Savannas	Prairies
Vegetation layers	Multiple $\geq$ 4	Multiple $\geq$ 3	2 to 3	2 to 3	2	1
Canopy Height-ft	90+	70-90	60-90	20-60	20-60	Not applicable
Tree Form	Narrow crowns, clean trunks	Narrow crowns, clean trunks	Somewhat spreading crowns, clean trunks	Spreading crowns, some lower branches	Wide-spreading crowns, lower branches typical	Not applicable
Canopy closure	90-100	90-100	80+	30-90	10-30	0-10
% Understory Cover	50-100 dense	50-100 dense	30-50 patchy	10-30 scattered	5-10 sparse	0-10
Ground Layer Cover	Dense in spring, patchy to sparse by midsummer	Dense to patchy in spring, patchy to sparse by midsummer	Dense to patchy in spring, patchy to dense by midsummer	Patchy to dense all season	Dense all season	Dense all seas
Ground Layer Plants	Rich diversity of spring ephemerals, and ferns; few summer/fall forbs	Moderate to low diversity of spring ephemerals, and ferns, few summer/fall forbs	Moderate to low diversity of spring ephemerals, and ferns; abundant C3 grasses, sedges, and summer/fall forbs	C3 and C4 grasses, sedges, diversity of forbs all season	C4 grasses, sedges, diversity of forbs all season	C4 grasses, sedges, diversit forbs all seasor
Topography and Landform	Protected valleys, ravines, bluff bases, lower slopes of northerly aspects, fire shadow areas	Mid and upper slopes of northerly aspects, ravines, fire shadow areas	Mid and upper slopes of southerly aspects, fire prone landscapes	Steep upper slopes of southerly aspects, narrow ridges, broad ridges, fire prone landscapes	Level to gently rolling topography, steep loess hills, broad ridges	Level to gently rolling topograp steep loess hills broad ridges
Soils	Deep ($\geq$ 3') loams, nutrient rich, high organic matter	Moderate depth (24-36") silt loams, moderate organic matter	Moderate depth (20-36") silt loams, moderate organic matter	Shallow depth (<20"), droughty, often rocky and or nutrient poor	Wide range of soil types from shallow to deep, variably rocky	Wide range of s types from shal to deep, variabl rocky
Fire Regime	Very infrequent (30+years), and/or low intensity fires	Infrequent (20+ years), and/or low intensity fires	Low to moderate intensity fires every 3 to 15 years	Low to moderate intensity fires every 3 to 5 years	Moderate intensity fires every 1 to 3 years	Moderate to hi intensity fires e 1 to 3 years
Dominant Trees	Red oak, sugar maple, white ash, basswood, walnut	White, red, and black oaks, hickories	White, black, scarlet, chinkapin oaks, hickories, shortleaf pine	Post, blackjack, chinkapin, bur, white oaks, shortleaf pine	Bur, chinquapin, white oaks	Not applicable
Characteristic Plants	spicebush, paw paw	Flowering dogwood, rough-leafed dogwood, mulberry	woodland brome	wild quinine, wood reed	rattlesnake master	compass plant

METHODS

Nine attributes are used to compare each major natural community. Canopy closure is perhaps the single most important attribute, but topographic roughness coupled with predicting fire behavior patterns and propagation is equally important.

DISCUSSION

The revised "Terrestrial Natural Communities of Missouri" describes 91 distinct natural communities. These fall under major community types including forest, woodland, savanna, prairie, glade, wetland, cliff, and cave. Landscapes varied in the coverage of tree species ranging from 10% near prairies to 100% in deep forests. The 1985 classification system broke out this broad ranging tree canopy cover into 2 major community types: forest and savanna. Subsequent work on savanna classification throughout the Midwest resulted in standardized definitions and use of woodlands (Nuzzo 1986, Faber-Langendoen 2001). Faber-Langendoen offers a standard of 10 to 25% tree canopy cover for savannas while this author rounds the number off to 30% since the difference appears to be arbitrary and unrelated to any major ecosystem or species function.

Each of the major natural community types described below is summarized from descriptions presented in the 2001 edition of the "Terrestrial Natural Communities of Missouri" and natural community distributions are based on Nigh's (2002) "Atlas of Missouri Ecoregions."

Forest

Trees dominate forests and the canopy is closed with trees reaching heights of 60-100+ ft. Forests are multistoried with a canopy, a subcanopy of small trees (10-30 ft.), shrubs and saplings (3-10 ft.), and the ground flora (0-3 ft.). Maximum longevities of dominant tree species range from 200 to 400 years. Canopy trees have narrow crowns and clean boles. The understory is often dense with the result of little light penetration to the ground layer by summer. Trees, shrubs, woody vines, perennial forbs and ferns are predominant. The ground flora often has a rich assemblage of spring ephemeral herbs. The 2 major forest groups are upland forests and bottomland forests. Upland forests occur on a variety of soils and parent materials. Bottomland forests occur on periodically flooded alluvial soils.

Missouri's presettlement forests covered approximately 20% of the state. Today, forests cover around 7 million acres, or about 16% of the state. However, only about 10% of our forest acreage exceeds 90 years in age since the extensive logging of the late 1800's.

Fifteen forest natural communities are currently recognized on the basis of soil moisture and substrates:

Dry-Mesic Loess/Glacial Till Forest
Mesic Loess/Glacial Till Forest
Dry-Mesic Limestone/Dolomite Forest
Mesic Limestone/Dolomite Forest
Dry-Mesic Chert Forest
Dry-Mesic Sandstone Forest
Mesic Sandstone Forest

Dry Mesic Sand Forest
Mesic Sand Forest
Dry-Mesic Igneous Forest
Dry-Mesic Bottomland Forest
Mesic Bottomland Forest
Wet-Mesic Bottomland Forest
Wet Bottomland Forest
Riverfront Forest

Important Natural Processes of Forests

Natural disturbances in upland forests are typically of low to moderate intensity (killing single trees or small groups of trees but not stand replacing) and frequency. Wind throw, flooding and soil saturation, insect and disease outbreaks, ice storms, severe droughts and surface fires are causes of natural tree senescence. Prior to settlement, ground fires burned approximately every 20-50 years in highly dissected terrain. Fires and severe droughts would have been frequent enough to eliminate the development of a thick understory and mesophytic species, but likely were infrequent enough to allow for periodic oak regeneration. Ice storms and wind throw events cause canopy gaps of a quarter acre to 10 acres at a return interval of 800 years (Rebertus 2001) across a Missouri forest landscape.

Flooding and soil saturation are the main factors influencing the development of bottomland forests. The intensity, frequency, duration and depth of flooding influences which tree species will dominate in a bottomland forest. Intensive, high energy (headwater) flooding occurs at the upstream and outer meander bends of a river. This type of flooding results in deposition of more coarse sediments and abrades and scours the landscape. Riverfront forests develop under this flood regime. Extensive, low energy (backwater or slackwater) flooding occurs at the downstream end of the floodplain and back from the active channel zone. Mesic, wet-mesic and wet bottomland forests develop under this flood regime.

Woodland

Woodlands are natural communities with an overstory of trees ranging from 30 to 100% canopy closure with a sparse understory (or midstory) and a ground layer rich in forbs and graminoids. Canopy heights of trees range from 20 to 90 feet depending on site conditions. The ground layer has a patchy to dense cover all growing season as opposed to forests where ground layer cover peaks in spring. Canopy trees often have spreading crowns and some lower branches, particularly on drier sites. Maximum longevities of dominant tree species range from 200 to 400 years. The open understory (10-50% cover) allows enough sunlight to reach the ground to promote a ground layer with grasses, sedges, legumes and numerous composites. Oaks dominate most woodlands but oak-hickory and oak-pine mixtures also occur. Enough light reaches the floor to allow for the establishment of the canopy trees. While woodlands are highly variable in overstory structure, the presence of an open understory and a rich herbaceous layer link the variety of expressions of this natural community type. A high-quality upland woodland site of a few hundred acres can harbor 300+ vascular plant species.

Climate, fire, grazing by elk and bison, landforms, bedrock geology, soils, and hydrology all influenced the development of these communities over the last several thousand years. Plants and animals of this natural community occur with greater or lesser abundances in relation to a complex gradient of soil moisture, the amount of sunlight reaching the ground, the frequency and intensity of fire and grazing, and in some cases the nature of flooding and soil saturation. Summer and fall blooming herbaceous plants are abundant. Plant species of the grass, sedge, composite, legume, milkweed and rose families dominate the ground cover. Oaks and/or pines dominate the overstory, and the midstory or understory is characteristically open.

Woodlands may have covered a third of Missouri prior to European settlement. Today, approximately 100,000 acres of Missouri's woodlands retain substantial pre-European settlement integrity. However, up to 6 million acres of degraded woodlands may occur, primarily in the Ozarks. Many woodlands, particularly on dry sites, have old-growth oaks and pines. Old-growth conditions in woodlands are important for the conservation of biological diversity. However, old-growth woodlands are often not consistent with our old-growth preconception of cathedrallike forests. In comparison to old-growth forests, old-growth woodlands have less coarse woody debris, fewer trees and much shorter canopy heights.

Eighteen woodland natural communities are currently recognized on the basis of soil moisture and substrates:

Dry Loess/Glacial Till Woodland
Dry-Mesic Loess/Glacial Till Woodland
Dry Limestone/Dolomite Woodland
Dry-Mesic Limestone/Dolomite Woodland
Dry Chert Woodland
Dry-Mesic Chert Woodland
Dry Sandstone Woodland
Dry-Mesic Sandstone Woodland
Dry Sand Woodland
Dry-Mesic Sand Woodland
Dry Igneous Woodland
Dry-Mesic Igneous Woodland
Upland Flatwoods
Bottomland Flatwoods
Sinkhole Flatwoods
Dry-Mesic Bottomland Woodland
Mesic Bottomland Woodland
Wet-Mesic Bottomland Woodland

Natural and Anthropogenic Processes of Woodlands

Regular surface fires are integral in structuring and maintaining woodlands. Fires promote an open understory and allow for a diverse and thick ground cover of woodland plants. Tree dendronchronologists dated fire scars on fire-sensitive trees, including post oak, shortleaf pine, and red cedar. Prior to the presettlement era, surface fires occurred every 2 to 24 years, with an average fire return interval of about 6 years in Missouri woodlands (Guyette and Cutter 1991, Guyette and Dey 2000). Periodic fire-free intervals of 10 to 20 years on some sites allowed for sporadic recruitment of oaks and pine into the overstory (Johnson 1992).

Fire burns across a natural landscape creating a patchwork quilt of microhabitats in woodlands. Plants found in prairies and forests occur in woodlands depending on light and soil moisture levels. Other plants, such as stiff aster (*Aster linariifolius*) have a high degree of fidelity to woodlands. Certain plants may be abundant in woodlands, such as New Jersey tea (*Ceanothus americanus*), but they also occur in prairies. Other plant species occur in woodlands but may have a greater abundance in forests, e.g., wild geranium (*Geranium maculatum*). Woodlands may take on more of a forest aspect with an increase in shading from trees or shrubs. Likewise, on drier sites with more frequent fire, a more open canopy will foster prairie dominants such as little bluestem (*Schizachyrium scoparium*).

Historically, humans caused most fire ignitions in Missouri. Although thunderstorms are common in the state, lightning ignites few fires according to Guyette and Dey (2000). Throughout the Midwest, the pattern was similar, with most pre-European settlement fires being ignited by Native American populations (Pyne 1986). However, the true role of lightning may be underestimated because of the tendency to infer that present day lightning strikes cause a limited number of natural fuel ignitions. Lightning-ignited old-growth, hollow trees often burn for several days as observed on public lands where old growth has continued developing. This author postulates that 3 conditions that were present prior to European settlement greatly impact the probability of lightning-caused natural fires: 1) That the condition of the historic natural fuel types has changed from one of fast-drying grass/sedge/herb cover to slower-drying forest/woodland leaf litter; 2) That much of the present day tree cover is young to mature second growth in which the ratio of hollow, old-growth trees to young trees is far less than the time of settlement; and 3) That current day fuels are so highly fragmented or rendered insignificant as to limit widespread propagation of fire spread.

Historical records indicate that most fires occurred in the fall with less frequent fires occurring in spring and a few taking place in winter or summer.

A combination of flooding, soil saturation and fire influence the development of bottomland woodlands and flatwoods. Fluvial dynamics that structure bottomland forests have similar effects in bottomland woodlands. As in forests, drought, wind throw, ice storms, soil saturation, and similar insect and disease factors also determine woodland structure. In the presettlement period, grazing by elk and bison also influenced woodlands (McCarty 1998) but a lack of data precludes any definitive conclusions as to its impacts.

Flatwoods

Flatwoods are a type of woodland that occur on sites characterized by the presence of a claypan or fragipan. A claypan is a slowly permeable subsoil horizon that contains more clay than the horizons above it. It is typically hard when dry and plastic when wet. It creates ponding on the soil surface under saturated conditions and cracking when dry (Hausenbuiller 1985). A fragipan is a loamy, brittle subsurface soil horizon formed of silt or fine sands with a low degree of permeability. Like a claypan, it creates ponding on the soil surface under saturated conditions and becomes cementlike when dry. Both fragipans and claypans restrict root development and create droughty soils in summer and saturated conditions from fall to spring. Fragipans typically develop in loess deposits on ridges and slopes of less than 10% (Krusekopf 1963). Claypans occur in sinkhole ponds (Haefner 1983) on till plains (Taft et al. 1995) and on ancient alluvial terraces (Robertson et al. 1984). Flatwood soils are universally acidic, deep and level to gently sloping. Plants of flatwoods must adapt to seasonally wet (winter and spring) conditions due to a perched water table as well as summer droughts. Local openings and small ephemeral ponds that retain water in the spring are characteristic of some flatwoods. There are three types of flatwoods: upland, sinkhole pond, and bottomland.

Historically, extensive upland flatwood areas occurred on the high, broad ridges of the Salem and Springfield plateaus in the Ozark Highlands Section (Schroeder 1981, Ladd and Heumann 1994). Scattered sinkhole pond flatwoods occur in karst terrain throughout the Ozark Highlands Section while large areas of bottomland flatwoods historically occurred in the Mississippi Alluvial Basic Section (Robertson et al. 1984, McCarty 1998).

Savanna

Savannas are grasslands interspersed with open-grown, widely spaced, orchard-like scattered trees, or groupings of trees. Savannas are distinguished from woodlands because they are strongly associated with large prairies and are generally dominated by prairie grasses and herbs.

These open-grown, widely spaced, orchardlike stands of trees associated with prairie landscapes generally require the type of topography conducive to frequent, high-intensity fires. Savanna topography is associated primarily with gently rolling plains underlain by Pennsylvanian limestone and sandstone in the unglaciated Osage Plains Section and the Central Dissected Till Plains Section. However, savannas may occur anywhere where upland topography is gently rolling to level, regardless of geologic substrate. Their strongest affinity is to gently rolling plains where prairie also occurs. Savanna natural communities are described based on soil moisture and various soil substrates. They are named using the underlying substrate when areas of bedrock or substantial residual rock occur near the soil surface. Moisture modifiers are limited to the primary moisture regime associated with the rock substrate and overlying soil. Nearly all rock substrate savannas are dry mesic, while those found on the deeper soils of glacial till or loess are both mesic and dry mesic. No wet mesic or wet savannas are known because either few extant examples remain, or these are too small to function as savannas. Sand savannas are named for the wind or alluvial-deposited sandy soils of terraces and broad level ridges, especially characteristic of the Mississippi Alluvial Basin Section. Because of the difficulty in distinguishing dry to dry mesic soils of sand savannas, and owing to the topographic irregularities of the landscape, the typical sand savanna has no moisture modifier.

Savanna structure is primarily 2 layered: scattered orchardlike groves of trees and prairie. Shrub thickets occur, especially on the northeast-trending lee side of hills or in upland drainage where fire behavior was less severe. The savanna landscape varies across prairie regions. Open prairies are interspersed with widely scattered trees, or variably sized island groupings of trees. The key to classifying savanna is to map and describe continuous assemblages of scattered trees on a scale greater than 15 acres. Savanna flora and fauna must be adapted to full sun, frequent fire, and (prior to settlement) grazing by native herbivores.

Three primary geologic factors strongly influence the development of savanna natural communities: glacial history, development of the coast plain embayment, and the erosion resistance of upland plateaus. Glaciers leveled landscapes in northern Missouri, pulverizing bedrock and laying down a thick mantle of glacial till. This gently rolling plain was conducive to the frequent and rapid spread of wildfire, drying winds racing across the Great Plains, and perhaps to the adaptability of roaming bison herds. The relatively warmer, drier past climates of the recent post-glacial retreat following the Nebraskan and Kansan ice sheets aided in the development of prairie and savanna. South of the glacial limit, the Ozarks Plateau was uplifted from a former level plain, to be dissected by many present day streams and rivers. Despite frequent uplifts of the Ozarks Plateau followed by strong erosion cycles, certain portions of the Ozarks remained relative level, creating expansive plains. These occur along a line dissected by Interstate 44 from St. Louis to Joplin, and along Highway 63 from Rolla to West Plains. In the Lowlands Section, an expansive, sand-laden elevated floodplain resulted from the immense forces of glacial meltwater sediments, wind-driven alluvial sand mounds, and earthquake uplifts. This elevated, sandy plain was conducive to rapidly drained soils, wildfire, drought, and thus the development of prairies and savannas.

Savannas, prairies, glades, and open woodlands -- all are direct reflections and inextricably linked to natural or man-caused fires, and relicts of once common grazing and browsing by expansive numbers of American bison, American elk, and deer. But by far, the occurrence of fire -- and its influence dependent upon topography, subhumid temperate climate, an evolved burnable vegetation, and a high number of “burnable” days -- all lend to the undeniable historical presence of fire. Large expanses of level to nearly level landscape coupled with frequent fire will eventually lead to the development of either prairie or savanna. Native Americans perpetuated the presence of fire for as long as 5,000 years, and certainly influenced the character of the natural landscape.

Savanna tree canopy cover is generally less than 30%. Open woodlands generally exceeding 20 acres or greater, dominated by grasses and with a tree canopy cover less than 30% may fall into the savanna classification, especially if these are directly associated with prairie natural communities or have a strong prairie vegetation dominance. Savanna natural communities vary statewide because of differences in soil moisture, soil substrates, or characteristics of a natural division or section. In general, 3 primary vegetation associations dominate savanna natural communities. In the Central Dissected Till Plains Section, bur oak groves once dominated dry to dry-mesic prairie areas underlain by glacial till soils. Chinquapin oak co-dominated on the driest, steepest loess hills of northwest Missouri. Post oak savanna covered level uplands of the Springfield Plain Subsection and Central Plateau Subsection, especially along the Interstate 44 corridor and Highway 63 corridor from Rolla to Thayer. In the Springfield Plain Subsection, chinquapin oak and post oak often share dominance where associated with limestone/dolomite bedrock. Rock outcrops on prairies or on rugged, hilly terrain dominated by shrubs such as wild crab, hawthorn, rough-leaved dogwood, and winged sumac are often savannalike in character, but are primarily considered part of the prairie natural community.

Savanna communities are species-rich natural communities, with most richness found in the understory layer. For example, some 24 tree species grow on Bennett Spring Savanna near Lebanon. Beneath this sparse tree canopy grows 243 forb, 41 grass, and 20 sedge species.

Because of limited research and the nearly complete elimination of savannas, little is known of the ecological role that animals played in savanna communities. The American bison, elk, gray wolf, red fox, and coyote were abundant mammals. Birds thought to occur in savannas included warbling vireo, great crested flycatcher, lark sparrow, northern oriole, blue grossbeak, eastern bluebird, and red-tailed hawk. Probable savanna-inhabiting reptiles include the ornate box turtle, western slender glass lizard, prairie kingsnake, and bullsnake.

MANAGEMENT IMPLICATIONS

Missouri's landscape covered in trees ranged from 10 to 100 % and is divided into 3 primary natural community types: forest, woodland, and savanna. Attributes chosen to delineate each strongly correlate topographic roughness and its concomitant potential fire behavior with the distribution and occurrence of each. True forest was confined to fire-shadow landscapes, often occurring on north- and east-facing slopes, ravines, or riparian/floodplain areas. Woodlands occupied the majority of those areas considered as "forest" today. Many of today's modern, fire-starved forests were in fact once more open, fire-dependent woodlands. Savannas are strongly associated with gently rolling plains and prairies.

To what extent that forest, woodland, and savanna natural communities covered the state may never be known. Efforts are under way to develop a historic vegetation map of Missouri by programming all of the historic witness tree information along with other land survey records. This information will be extrapolated along with chain distance data for trees near and along survey boundaries, and then correlated to topography, historic land descriptions, autecological understanding of species adaptations to each natural community, and fire history/behavioral effects.

Managing Missouri's forest, woodland, and savanna natural communities requires an understanding of what factors threaten them. Society's understanding of Missouri's historic natural vegetation, the chronological sequence of events that dramatically changed it, and awareness of high-quality examples is very limited. Many people assume that Missouri's current forested landscape in the Ozarks is the same forest that our European ancestors experienced. It is not. The concept of disturbance ecology is critical toward understanding what is essential in managing forest, woodland, and savanna health.

Threats to Forests

The primary threats to forests, as for most other terrestrial natural communities, are habitat degradation and loss, and non-native species invasion. Major categories of habitat degradation and loss include land conversion for agriculture, urban and commercial developments, livestock overgrazing, road building, fire suppression, water development (dams, flood control, drainage projects, navigation access), intensive logging, and pollutants (including siltation). Conversion of forests to cropland, pasture and urban developments remains the primary threat. Extensive conversion of bottomland forests to agriculture has occurred in Missouri, particularly in the Mississippi River Alluvial Basin Section and in floodplains of larger rivers and streams.

Habitat fragmentation is the disruption in the continuity of otherwise naturally blended mosaics of natural communities. Fragmentation might include an area of forest pockets surrounded by agriculture or containing an interior old field patch. Road density has been shown to have a positive correlation with forest fragmentation (Trombulak and Frissell 2000). Forest fragmentation increases the amount of forest edge habitat. Increasing the amount of forest edge (defined as the boundary between forest and a nonforest land type) has several detrimental effects on forest natural communities. These include decreasing the nesting success of forest-interior Neotropical migrant songbirds (Robinson et al. 1995) to increasing the amount of weedy and exotic species in forests. Forest landscapes in the Current River Hills and St. Francois Knobs and Basins subsections remain relatively unfragmented. Moderate forest fragmentation has occurred in the Osage River Hills, Meramec River Hills, White River Hills, Inner Ozark Border and Outer Ozark Border subsections. Most other sections and subsections show heavy fragmentation effects (Spencer et al. 1992).

Livestock grazing, particularly at high densities and prolonged periods, causes extensive damage to forest natural communities (Spurr and Barnes 1980). Livestock grazing promotes weedy, grazing "increaser" species such as buckbrush (*Symphoricarpos orbiculatus*) and gooseberry (*Ribes* spp.) and reduces the floristic diversity of the forest floor. Heavy grazing can cause entire changes in natural community composition and structure. In addition, grazing can cause excessive soil compaction and erosion. This also applies to woodlands and savannas.

A number of exotic species threaten the biodiversity of Missouri's forests. Several introduced fungal pathogens have created problems for trees, including Dutch elm disease fungus (*Ceratocystis ulmi*) on American elm (*Ulmus americana*), chestnut blight *(Endothia parasitica*) fungus on Ozark chinquapin (*Castanea ozarkensis*) and a canker (*Sirococcus clavigignenti-juglandacearum*) that impacts butternut (*Juglans cinera*). Of introduced insects, the gypsy moth (*Lymantria dispar*) threatens to damage oak-dominated forests and woodlands. Several exotic plant species pose large problems for the biota of our forests. Garlic mustard (*Alliaria petiolata*), a shade-tolerant and invasive exotic species, poses a growing threat to the herbaceous flora of our forests. Bush honeysuckles, (*Lonicera morrowii and L. maackii*), Japanese honeysuckle (*L. japonica*) and wintercreeper (*Euonymus fortunei*) also invade forests and decrease the diversity and cover of herbaceous flora (Smith 1993).

An overpopulation of white-tailed deer *(Odocoileus virginianus*) can cause negative shifts in forest composition and structure (Anderson 1997, Augustine and Frelich 1998). In addition, there is some evidence that the coverage of the invasive exotic garlic mustard increases with heavy deer browsing. Stress from deer browsing begins to occur to plant populations at deer densities between 25 to 50 deer per square mile.

Bottomland forests have changed in composition with hydrological modifications to streams (Brinson 1990). Most bottomland forests along the larger rivers occur outside of flood-control levees. These forests receive heavy silt loads, flow velocities are high, and water levels rise more quickly (Fredrickson and Reid 1990). Many bottomland forests outside of the levees along the Missouri and Mississippi rivers have shifted from mesic and wet-mesic bottomland forests to riverfront forests with the advent of levees, navigation structures and heavy stream sediment loads (Bragg and Tatschl 1977, Yin et al. 1997). Similar changes have occurred in bottomland.

Forest Protection and Management

True forest natural communities are often associated with deep ravines, fire shadow landscapes, and floodplains. The extent of acreage for these natural communities is much more limited than their woodland counterparts in the "forested" regions of the state. High-quality bottomland or floodplain forests are among the most endangered forest types in Missouri. For example, only one high-quality bottomland forest exists along any portion of the Missouri River floodplain today. Pioneering sycamore, silver maple, river birch, box elder, and cottonwood today generally follow bottomland forest regeneration. Few oaks and hickories dominate as they did at time of pre-European settlement. Efforts to reseed or plant hardwood oak and hickory species into bottomland forests are needed. Deer overpopulations and problematic non-native plant species must be controlled or prevented from impacting such restoration sites.

Fire propagates from associated woodlands and savannas into forest natural communities. The moist environments of north- and east-facing slopes, some riparian zones, and vegetation composition dampen fire effects. However, fire did burn into these natural communities, often affecting only the ground cover. Some stand-replacement fires did occur at times of extreme drought. Managers should conduct controlled burns in forested areas, and study the effects. For example, the Missouri Department of Natural Resources conducted a prescribed burn in the 1,000-acre Big Oak Tree Natural Area. This burn consumed forest floor leaf litter and small woody debris over an otherwise seasonally wet bottomland hardwood forest, resulting in a major increase in herbaceous ground cover, and may have stimulated oak regeneration.

Threats to Woodlands and Savannas

Woodlands, as are forests, are threatened by habitat degradation and loss, and non-native plant species. Most upland woodlands remain but bottomland woodlands and flatwoods have been largely converted to cropland or pasture. Woodlands suffer from similar habitat fragmentation problems found in forests. However, extensive unfragmented woodland acreages still occur in the Ozarks, particularly in the White River Hills, Current River Hills, St. Francois Knobs and Basins, and Osage River Hills subsections. Woodlands with dry soils are prone to invasion by the aggressive exotic, sericea lespedeza (*Lespedeza cuneata*), where this species is introduced along roadsides or clearings. Dry-mesic and bottomland woodlands may be invaded by garlic mustard on fire-suppressed sites. As in forests, woodlands are negatively impacted by livestock grazing, intensive logging, deer overpopulations and on floodplains, hydrologic alterations.

Fire suppression is the primary factor in habitat degradation of woodlands. In addition to lack of fire, the season of burning can have a great influence on the composition of the ground flora. Traditionally, resource managers have burned in midspring. Varying the seasonality of fires appears to be a critical component in restoring the natural disturbance regimes of woodlands (McCarty 1998). Many areas of the state have had 30 to 50 years of woody invasion since fire suppression, creating a heavy undergrowth beneath a more dense, second-growth stand of trees. An active woodland restoration program of thinning followed by prescribed burning every 1 to 3 years appears necessary to restore fire suppressed woodland systems (Taft 1997, McCarty 1998).

In the absence of fire, sites with dry soils tend to retain their woodland structure and plant composition for long periods (Pallardy et al. 1991, Johnson 1992). Essentially, woodlands can occur on dry soils as an"edaphic climax" type (Fralish 1997). However, in the absence of fire, dry woodlands can lose a large component of their conservative plant (Taft et al. 1997) diversity and cover (Anderson and Schwegman 1991, Taft 1997, McCarty 1998). Shortleaf pine requires ground fires every 5-30 years for successful establishment (White and Lloyd 1998) and many dry oak-pine woodlands currently lack adequate pine regeneration. Most of the state's dry sites can be readily recognized as woodlands, albeit in a degraded state. Stambaugh (2001) concludes that canopy gap disturbances alone are not sufficient in maintaining an overstory of composition of shortleaf pine, and that fire disturbances were possibly the only natural disturbances capable of maintaining shortleaf pine forest and woodland communities in the Ozarks prior to the early 1800’s. In broad vegetation ecology treatments, ecologists often call these areas dry oak and oak-pine forests (Delcourt and Delcourt 2000).

In contrast, fire-suppressed sites with dry-mesic soils typically succeed to a forest structure within 50-100 years (McCune and Cottam 1985, Haney and Apfelbaum 1990, Abrams 1992). In fire-prone landscapes, dry-mesic sites that historically supported woodlands now support forests due to fire suppression. Dry-mesic forests that developed from previous woodlands often show depauperate plant diversity and a lack of advance regeneration of canopy oaks (Haney and Apfelbaum 1990, Fralish 1997, McCarty 1998). Although from a first glance, many of Missouri's current forests would appear to resemble their pre-European settlement counterparts, they really do not. Many of Missouri's current dry-mesic forests were historically more open in the understory due to a frequent fire regime (Beilmann and Brenner 1951, Ladd 1991, Nelson 1987, Batek 1999). Woody vegetation has invaded most of the state's pre-European dry-mesic woodlands over the last 150 years due to fire suppression.

Shortleaf pine-oak woodlands historically occurred over a range of about 6 million acres in the Ozarks (Nelson 2002). Over 80% of Missouri’s historic oak-pine and pine woodlands have been converted since European settlement (Spencer et al.1992), primarily to degraded black oak *(Quercus velutina*) and scarlet oak (*Q. coccinea*) woodlands and forests (Batek et al. 1999). Between 1880 and 1920, frequent and severe wildfires, extensive logging of pine, and overgrazing caused the loss of shortleaf pine (Cunningham and Hauser 1992, Guyette and Dey 2000). Lack of seed trees and fire suppression currently impede the redevelopment of oak-pine woodlands in Missouri.

The first edition of “The Terrestrial Natural Communities of Missouri” indicated that perhaps 13 million acres of savanna occurred in Missouri prior to settlement. This number was extrapolated based on interpretations using the extent of prairie cover and descriptions of historic barrens, oak openings, and other open woodlands in which grasses dominated the ground cover. The revised estimate now discounts open woodlands that fall into the woodland natural community descriptions. The estimate is now restricted to the probability of savannas strictly associated with prairie regions, and relatively level upland plateaus. Woodland acreage encompasses much of the traditional “forested” Ozark Highlands Section.

The causative factors that eventually led to mass degradation, and in some cases total extinction, of Missouri woodlands and savannas include suppression of historic natural or anthropogenic fires, replacement of natural herbivores by domestic livestock grazing, logging, conversion to cropland, and seeding to cool season exotic grasses. Because most former woodlands and savannas (like their associated prairie natural communities) were floristically rich, these served as the primary foraging sites for domestic livestock that were allowed to range freely during European settlement. The richest savanna soils, especially in northern Missouri, were rapidly converted to cropland or intensively grazed.

Numerous early historical accounts reference the pervasive practice of burning the landscape by Indians, usually in the autumn. Joseph Mudd (1888) in the “History of Lincoln County” writes: “Annually, after this rank growth of vegetation had become frosted, dead, and dry, the Indians set fire to it and burned it from the entire surface of the country. When this annual burning ceased, the germs of underbrush and young timber began to grow.” This one single account echoes many numerous other excerpts taken from historical accounts as referenced by Ladd (1991) and Nigh (1992). Further conclusive evidence is offered to explain how former savannas rapidly suffered conversion to thickets of woody growth brought about in response to fire suppression and intensive, domestic livestock overgrazing. Intense grazing of formerly rich savannas, woodlands, and prairies for 150 years quickly removed the diverse mix of grass, sedge, forb, and shrub cover mantling the landscape. Now lacking adequate vegetative cover, soils were subject to severe erosion and depletion of their former organic richness and structure. Once depleted of their productivity and flammable vegetative cover, former savannas yielded to overgrazed vegetation usually typified by a low diversity, sparse ground cover, annuals, thorny shrubs, and non-native invasive cool-season grasses. Livestock producers subsequently attempted to revitalize range conditions on former savanna (and woodland) by clearing brush and secondary woody growth, annual burning, fertilizing, and seeding with cool-season non-native species. This further damaged and reduced plant species richness.

Only fragmented examples of former woodlands and savannas exist today. What remains is structurally altered as evidenced by old-growth, scattered, open-grown trees often choked by even-aged young stands of other tree species. Or in the case of woodlands, complexes of old-growth or virgin post oak occupy a matrix of younger, even-aged red oaks and red cedar. The ground cover is much reduced in cover, species richness, and abundance and is often choked by heavy leaf litter and dense underbrush. Savannas are endangered and should not be confused with the more abundant and sizeable open woodlands of the Ozark Highlands Section. No existing natural areas in which the principal natural feature is savanna exists while the number of woodland natural areas is much larger. The most important step in protecting true woodland and savanna natural communities is for land protection agencies to refine inventory criteria by identifying sizeable degraded examples for acquisition and restoration. The best opportunity areas for protecting savannas likely remain in northern and southwestern Missouri. Excellent opportunities exist for restoring and protecting woodland natural communities throughout the "forested" regions of Missouri.

Woodland and Savanna Protection and Management

McCarty (1998) and Packard (1997) are excellent references for outlining woodland and savanna restoration and management techniques. As defined by McCarty, restoration is an attempt to re-assemble functioning ecosystems from relict pieces of the originals, and to create an environment that can sustain them. An important step toward restoring existing savanna is to first find the best (but likely degraded) savanna landscapes remaining on public lands. Land managers and natural area inventory personnel must learn to recognize relict structural tree components often obscured in even-aged stands of other tree species. Equally significant is understanding the various early phases of savanna restoration. For example, the early stages of restoration (as described in McCarty) often do not resemble the floristically rich historic woodlands and savannas.

Two important steps are critical to managing and restoring savannas: 1) Reopen the midstory structure and reveal the original relict native savanna trees; and 2) Reinstate fire regimes. As explained by McCarty, the former admits light to the ground layer providing improved growing conditions that sun-loving plants need to grow and reproduce. Fires create and maintain an open understory, remove surface litter, and stimulate reproduction of herbs, sedges, and grasses. McCarty (1998) outlines the predictable stages of recovery for savanna natural communities providing that native propagules have survived and non-native species are not prevalent. The critical message to conservation/preservation entities is that, given the new classification system, no savannas are represented in the Missouri Natural Areas System for this major natural community type. While restorable savannas likely still exist, these are immediately endangered as time, the lack of light to the ground cover, absence of fire, and overgrazing diminish their recoverability.

State and federal agencies are actively restoring savannas and woodlands. The Mark Twain National Forest is partnering with The Nature Conservancy to restore over 10,000 acres of historic shortleaf pine/bluestem woodland in Carter County. The Missouri Department of Natural Resources is actively restoring approximately 40 acres of loess/glacial till savanna at Long

Branch State Park near Macon, and maintaining perhaps Missouri's most outstanding chert woodland landscape at Ha Ha Tonka State Park in Camden County. The National Park Service is restoring a savanna at Wilson Creek National Battlefield near Springfield in an effort to replicate the historic Civil War battlefield. The Missouri Department of Conservation is restoring dry chert woodland/dolomitic glades at Peck Ranch in Shannon County.

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USING ECOLOGICAL LAND CLASSIFICATION SYSTEMS TO IDENTIFY SAVANNA AND WOODLAND POTENTIAL IN MISSOURI

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ABSTRACT

The potential distribution and character of savannas and woodlands in Missouri varies by ecological region and landscapes within regions. The Missouri Ecological Classification System (ECS) is an effective framework for considering differences in savanna and woodland communities across the state and the potential of various landscapes to support them. This paper utilizes the ECS as a framework for communicating these ideas. Please access a power point presentation on the Web site listed below:

http://www.missouriconservation.org/documents/eco_land_class.ppt

FIRE HISTORY OF PANTHER CAVE HOLLOW

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ABSTRACT

Fire scars were identified on 12 cross-dated cut stumps, natural remnants, and live trees of shortleaf pine (*Pinus echinata*). Fire scar dates were used to construct a 393-year-long fire history near Panther Cave and Black Oak Hollows [Missouri Ozark Forest Ecosystem Project (MOFEP) Site 9]. The mean fire interval (MFI) was 4.4 years and ranged from 1 to 17 years during the period of record (1604-1996). The MFI at the site decreased significantly ($p<0.001$) from 7.2 to 3.9 years circa 1760 and is coincident with early migrations of eastern Native Americans and territorial expansion of the Osage. The Panther Cave site has had continued and frequent fire during the last 50 years compared to most fire history sites in the Current River watershed, which have had a marked decline in the frequency of fire over the last 50 years. The MFI for the period 1941 to 1996 (MFI = 4.8) was not significantly ($p=0.01$) different from the MFI for the previous 336 year period of record (1604 to 1940). Several severe fires that scarred a high percentage of trees occurred in 1780 (75%), 1801 (43%), 1806 (43%), 1820 (86%), and 1831 (50%). The 1780 fire at the Panther Cave Hollow site was coincident with the year in which the largest percentage of sites burned in the Current River watershed and had the highest percentage of trees scarred at any of the 26 fire history sties. The 1820 fire in which 86 percent of the trees were scarred is coincident with another severe fire in 1820 at a site (Huckleberry Hollow, MOFEP Site 4) 10 km southwest in which 56 percent of the trees were scarred and the growth of pine was abruptly reduced. The percent of trees scarred in fire years is inversely correlated with a drought proxy, pine ring width, and with the first difference of ring width indicating that the magnitude of fuel production in the year preceding a fire year contributes to fire size and intensity. Ecological principles are used to predict ecosystem responses to fire suppression.

INTRODUCTION

This study is part of an ongoing research project, the Missouri Ozark Forest Ecosystem Project (MOFEP), designed to investigate forest management impacts on multiple biotic and abiotic ecosystem attributes (Brookshire et al. 1997). A dendrochronological fire history of one of the research sites (MOFEP Site 9), here referred to as the Panther Cave Hollow site, is the subject of this report. Wildland fires are a highly variable phenomena controlled by fuels, climate, human population, and culture. These factors combine in complex ways to give each ecosystem a unique fire history. The events of these fire histories, in turn, can have long-term effects on the ecosystems. The objective of this research and report is to document the particular fire history near Panther Cave Hollow and relate this fire history to climate, cultural history, and the site's ecosystem.

STUDY AREA

The Panther Cave Hollow (MOFEP Site 9) study area is located (91∞ 07' 30", 37∞ 04' 30") approximately 5 km west and 3 km south of the Current River in Carter County, Missouri. The site lies in the highly dissected terrain of the Current River breaks of the Ozark Plateau with elevations ranging from 183 to 305 m. The study site is approximately 1 km^2 in area and consists of three small south- and west-facing watersheds adjoining Rogers Creek (Figure 1). The study area is surrounded by highly dissected terrain in all directions for at least 10 km. Dominant tree species occurring at the site are primarily oak with minimal representation by shortleaf pine.

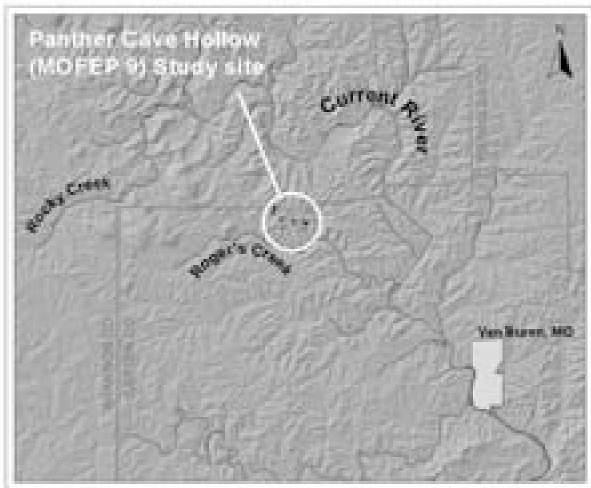

Figure 1

Map of the Panther Cave Hollow study site (MOFEP Site 9) with the locations of trees and pine remnants used to construct fire history at the site. The study site is about 3 km west of the Current River in the Missouri Ozarks. Pyrogenic characteristics of the site include watersheds that face south and west in the direction of the prevailing winds and aspects and slopes have high insolation, especially during the dormant season when most fires occur.

METHODS

Samples were collected over a 5-day period during the winter of 1997. Eighteen cross sections were cut from pine stumps, natural remnants, and live trees in the watersheds of Panther Cave, Black Oak, and an unnamed hollow within MOFEP Site 9. Fire scarred trees and remnants were located by walking south- and west-facing steep slopes throughout the study site. Slope, aspect, and orientation were written on each cross section collected. Cross sections were transported to the Missouri Tree-Ring Laboratory where they were surfaced with an electric hand planer and sanded or cut with a razor to expose the annual rings and fire scars. We measured the radius (pith to bark ring series) of the cross section that had the least amount of ring-width variability due to reaction wood, injury, or callus tissue. The radius measurement location was also chosen to maximize the number of rings measured. Ring-width plots were used for visual cross matching of ring-width signatures. Visual matching of ring-width patterns allows the weighing of important "signature years" over years with low common variability among trees. Plots also aided in identifying errors in measurement, missing rings associated with injury or drought, and fire years. COFECHA, software for quality control and cross dating of tree-ring measurements (Holmes et al. 1986), was used to assist in ensuring the accuracy of both relative and absolute dating of the samples by correlation analysis. Absolute dating of pine remnants was accomplished by cross dating them with a ring-width chronology constructed from live shortleaf pines (Guyette 1996b).

Fire frequency data was calculated from the composite fire chronology. A specialized fire history program, FHX2, (Grissino-Mayer 1995) was used to plot a summary of the fire scar record and for statistical analysis of fire events. Composite fire chronologies are commonly used for fire history research because statistics are based on many samples leading to a more accurate representation of the presence of fire at a particular site than would be obtained from single trees. For example, not all trees are scarred in a fire because of the great variation in fuels and bark thickness. Thus, several trees at a site are combined to give a better estimate of fire frequency. This type of analysis assumes that our 1 km study area burned as a single unit. Conversely, bias created from fires that left no scars on the sample trees likely equals or outweighs bias presented by partial burning of the study site.

RESULTS AND DISCUSSION

Dating and the Chrono-Sequence

Twelve of 18 samples collected were used in the fire history. Deterioration of the fire scar face, lack of cross dating, and redundancy was the justification for rejecting 6 of the 18 cross sections. The mean correlation in ring width between the study site trees and the Shannon County ring-width chronology (Guyette 1996b) was 0.48 (correlation ranged from 0.41 to 0.57). Samples had 155 annual rings on average and tree-ring dates ranged from calendar years 1604 to 1996 (Table 1). Fire scar dates ranged from 1638 to 1990 (Figure 2). All periods of the composite fire chronology after 1648 have at least 4 recorder trees but not more than 8.

Table 1

Fire scar, sample tree, and site data for the Panther Cave Hollow site (MOFEP Site 9).

Beginning year	1604
Last year	1996
Length of fire chronology	393
Total number of sample trees	12
Total number of recorder years	1854
Total number of fire scars	106
Average number of years per fire	17
Total number of fire years	81
Percentage of years with fire	20
Percentage of years without fire	80
Average degrees of slope of sample trees sites	19
Average degrees of aspect of sample tree sites	225
Area of the study site in km^2	1

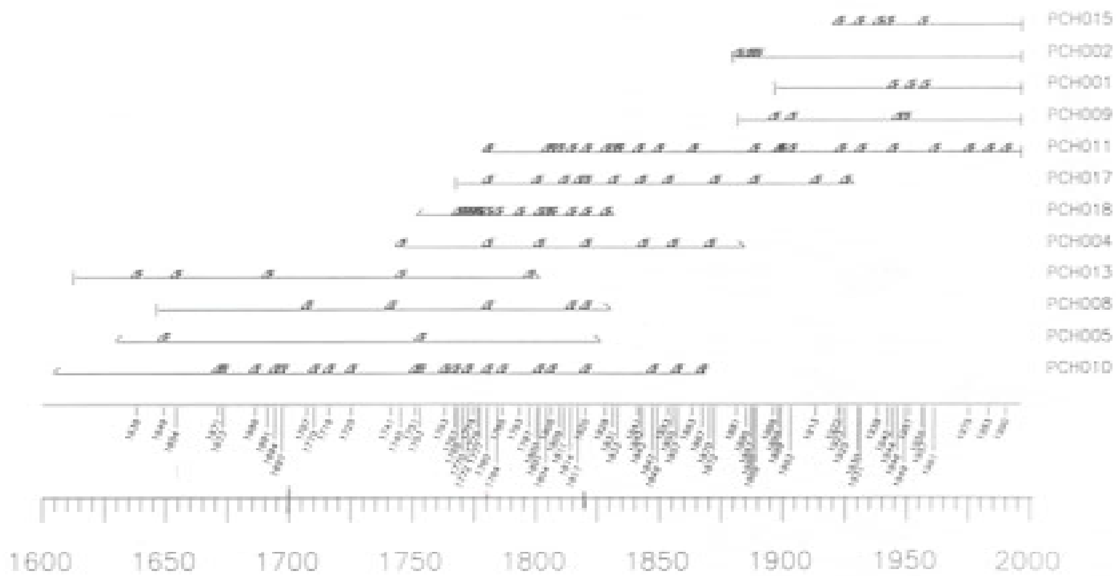

Figure 2

A plot of fire scar dates and period of record for sample trees and pine remnants illustrating the data and fire history at the Panther Cave Hollow site (MOFEP Site 9). A composite fire scar chronology with fire dates is given for the site at the bottom of the figure.

Fire Frequency

With the exception of the Depopulated Period (1604-1760), during which few people were living in the Current River watershed (Guyette 1997), the mean fire intervals for the different periods vary insignificantly (p=0.05) from one another for each period of record (Table 2). The Depopulated Period (MFI=7.2) had a significantly (p<0.001) longer MFI than all periods that followed. The MFI of the Modern Period (1941-1996) is not significantly different (p = 0.23) from the MFI of the periods between 1760 and 1940.

One of the most significant aspects of the fire history is the continued evidence of burning throughout the 1900s. Few fire history sites in the Current River watershed have evidence of burning after the 1940s (Figure 3). Recent burning at this site and consistent reoccurrence of fire over the past 393 years of record indicate that this site is an important example of continual and long-term effects of burning on an Ozark forest community. The most recent fire occurred on the Panther Cave Hollow site in April of 1997 and burned 18 acres before being suppressed. While other MOFEP sites may have undergone several (2 to 5) decades of changes due to fire suppression (e.g. changes in soil loss, organic matter accumulation, coarse woody debris, calcium cycling, invertebrate populations, vegetation dynamics) (Garza and Blackburn 1985) the Panther Cave Hollow site has undergone less than a decade of change following 393 years with a MFI of 4.6 years.

Typically fire intervals are not normally distributed and are best described by the Weibull distribution (Grissino-Mayer 1995). The Weibull median probability interval was 3.75 years with significantly short and long MFI being < 0.81 and > 8.8 years respectively (Table 3).

Considering that the last fire scar evidence at the study site was in 1990, this site is currently in a significantly long fire-free period.

Table 2

Fire interval statistics by time periods are given for the Panther Cave Hollow (MOFEP Site 9) composite fire chronology. The mean fire interval (MFI), standard deviation (STD DEV), and range are given in years.

PERIOD	DATES	MFI	STD DEV	RANGE
Depopulated	1604-1700	7.4	5.6	2-17
Native American	1701-1820	3.9	3.2	1-16
Euro-American	1821-1940	3.7	2.8	1-10
Modern	1941-1996	4.8	4.6	2-14
All periods	1604-1996	4.4	3.6	1-17

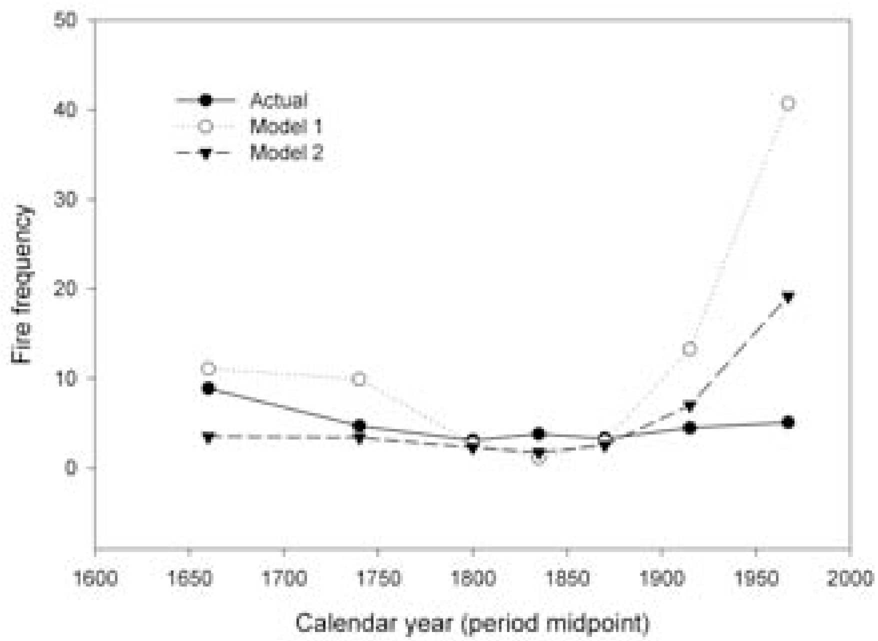

Figure 3
A drought proxy, an off-site regional shortleaf pine ring-width chronology derived from 39 trees is compared with the percent of trees scarred at the Panther Cave Hollow site. Note that the fires of 1780 and 1820 occurred in years with narrow pine rings.

Table 3

Weibull Distribution Exceedance Probability Table

Exceedance Probability	Associated Fire Interval
0.999	0.08 <-->
0.990	0.31 <-->
0.975	0.54 <-->
0.950	0.81 <--> significantly small intervals
0.900	1.24
0.800	1.93
0.750	2.24
0.700	2.54
0.667	2.74
0.600	3.14
0.500	3.75 <--- Weibull Median Probability Interval
0.400	4.42
0.333	4.92
0.300	5.19
0.250	5.64
0.200	6.16
0.100	7.60
0.050	8.88 <++> significantly large intervals
0.025	10.03 <++>
0.010	11.43 <++>
0.001	14.51 <++>

Fire Size, Severity, and Stand Replacement

There were several severe fires at Panther Cave Hollow in the past 393 years. The best historical evidence for quantifying fire severity is the number or percentage of trees that are scarred in a particular year. The fire of 1780 scarred 75 percent of the sample trees and, along with the fire of 1820, caused a significant decrease in mean ring width of sample trees (Figure 4). This is a large percentage of trees scarred in comparison to other sites in the Current River watershed. The year 1780 ranks as one of the most severe fire years before Euro-American settlement in the Ozark Highlands and other parts of eastern North America (Guyette and Dey 1995). Because of its wide occurrence, one might expect that at least in some areas this fire was a stand replacement disturbance event, particularly at the Panther Cave Hollow site where a high percentage of trees was scarred. Some of the stands at Panther Cave Hollow may have been replaced 3 times over the last 217 years -- once in 1780 (fire), once in 1904 or 1937 (logging), and in the experimental harvest of 1996 (logging).

Six out of the 7 recorder trees (86 %) were scarred in 1820. This is the highest percent of trees scarred at any Ozark fire history site in any year. The second highest percent of trees scarred in a single year was also in 1820 at a fire history site on Mahans Creek 27 km west of the study site. Although many sites were burned in the north and west sections of the Current River watershed in 1820, the Panther Cave Hollow site had the highest percentage of trees scarred and is one of only 2 sites in the south and east sections of the watershed with any evidence of fire in 1820. Pine trees at the Huckleberry Hollow site (MOFEP Site 4, also on the north side of the Current River) show abrupt growth declines, which begin in 1820 (Guyette and Dey 1997).

Correlation of the percentage of trees scarred in various years among sites in the Current River watershed is a function of distance. The percentage of trees scarred among sites that are far apart are generally not significantly correlated while sites that are closer together are significantly correlated (Guyette 1996a). During the Transition Period (1760-1820), the percent of trees scarred at the Panther Cave Hollow site were significantly correlated with the percent of trees scarred at sites up to about 12 km distant (Table 4).

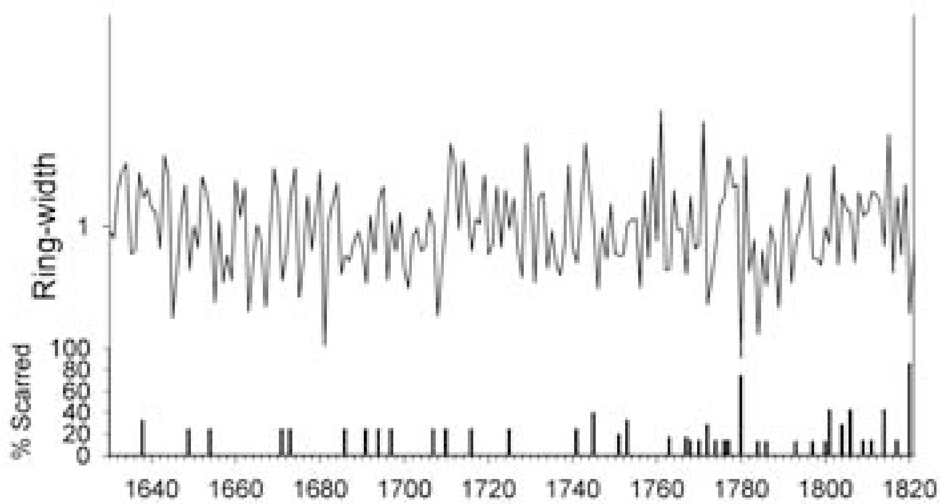

Figure 4

Fire model predictions for different time periods at the Panther Cave Hollow site show that this site burned more frequently than most after 1890.

Table 4

Correlations between the percent of trees scarred at Panther Cave Hollow and the percent of trees scarred at other nearby sites. Correlations are given for three periods and the data is ranked by the distance of sites from the Panther Cave Hollow site.

SITE NAME	1670-1760	1761-1820	1821-1880	DISTANCE (km)
Mill Creek	-0.18	0.27*	0.00	4
Mill Mountain	-0.09	0.32*	0.14	8
Huckleberry Hollow	-0.11	0.36**	0.31**	8.5
Nordic Hollow	0.23	0.40**	0.11	10
Blue Spring	0.11	0.22	0.31**	11
Deer Run	0.09	0.34**	0.15	12.5
Jerktail Mountain	-0.10	0.09	0.13	22.5
Mill Hollow	-012	-0.09	0.27*	23
Big Creek	0.01	0.00	-0.16	33

Cultural and Fire history at Panther Cave Hollow (MOFEP 9)

Stevens (1991) stated that there were 3 periods of westward migration for the Cherokee, Delaware, and Shawnee. The first period of migration took place during the years of Spanish colonization after 1763. The Spanish urged eastern tribes to move westward to buffer Euro-American settlers from the Osage. This date is consistent with an abrupt and significant ($p<0.01$) increase in the frequency of fire in the composite fire interval after 1760 (Figure 2) and may be associated with early visitations by the Shawnee. The proximity of a Shawnee camp (Stevens 1991), approximately 3 km east of the Panther Cave Hollow, may account for the abundance of ignitions at the study site –an important fire ignition source that maintained a MFI of 3.3 years in a highly dissected landscape.

Between 1630 and 1760, fires were relatively frequent (MFI=7.2) and indicate anthropogenic origins. A short reach of the Current River (about 7 km) near the mouth of Rogers Creek and about 6 km from MOFEP Site 9 has 26 identified archaeological sites (unpublished data). Two large archeological sites (> 100 m in length) occur at the mouth of Rogers Creek and these sites may have been occupied many times over the last 10,000 years. However, these sites were probably not extensively occupied during the period of fire record before 1760 because better camping and village sites most likely attracted transient hunters and gathers of the Quapaw and Osage who traveled in the area during this period. Osage territorial expansion, facilitated by the acquisition of equestrian technology, peaked in 1770 (Wiegers 1985) and included the region of the Current River watershed. Spring season hunts of the Osage were for bear and beaver in the Ozarks Highlands and took place during February and March (Foley 1989). Westin (1992) found March to be the month with the greatest number of fires and area burned in the Current River region. Subsequent acquisition of European technology further changed Osage culture. Hunting became a commercial as well as subsistence activity. They hunted in more distant territories and in smaller groups, 2 changes that could have resulted in increasing fire frequency at the Panther Cave Hollow site.

Historical population densities and cultures may explain why burning has continued over the last 50 years at the Panther Cave Hollow site, despite state and nationwide fire suppression efforts. Contemporary fire suppression and detection efforts may have been hindered by the remoteness of the site. Historically, as is today, the Current River inhibits traffic from the east and north. The site is nearly a 1 hour drive by road from the nearest communities (i.e. Eminence, Ellington, Winona, and Van Buren), transecting very topographically rough terrain. The remoteness of the site from centers of population may have limited both the effectiveness and priority of fire suppression efforts, but likely not the number of hunters and subsequent ignitions on public land. Detection, response, and access to the site's interior may have greatly limited the value of same-day fire suppression response. Road conditions to the site were probably worse in the past than they are at present, contributing to an even slower suppression response in the past than is possible today. Likewise, fire suppression efforts in the area may have been a low priority because of the few (approximately 17) human structures that exist within a 108 km^2 area surrounding the site. Proximity to human population in modern times is not only a factor in frequency of ignitions, but also as a source of detection and suppression.

Early Population and Fire Frequency

Fires were relatively frequent (2.7 fires per decade) at the Panther Cave Hollow site between 1760 and 1820. Guyette and Dey (1997) present an equation relating fire frequency to population at Huckleberry Hollow (MOFEP Site 4), about 8 km north of Panther Cave Hollow. A natural log transformation of census data of human population and early population estimates were highly correlated ($r = 0.84$, $p < 0.05$) with the number of fires per decade during the period 1770 to 1910.

$$y = 4.67 + 1.17(\ln[x]) \qquad (1)$$

where; y = fires per decade,
x = the natural log of population density (human/km^2),
$r^2 = 0.71$.

Fire event data from the Panther Cave Hollow can be used to estimate the historical population density at the Panther Cave Hollow site. Estimates of population density around the Panther Cave Hollow Site can be derived by substitution of actual y values from the Panther Cave Hollow composite fire scar chronology (Table 5). Thus, during the Depopulated Period before 1760, there are estimated to have been about 6 humans in the 100 km^2 around the Panther Cave Hollow site during the spring and fall fire seasons. During the period 1760 to 1820, 19 humans are estimated to have visited the vicinity of the study site. These low population density estimates indicate that the only use of the area around the site was probably sporadic and seasonal use by hunters.

Table 5

Actual fires per decade at the Panther Cave Hollow site and human population density estimated by Equation 1.

PERIOD	Y (fires/decade)	X (human/km^2)
1630-1760	1.31	0.06
1761-1820	2.73	0.19

Fire Size, Intensity: Climate or Culture Forced?

Henry Rowe Schoolcraft (Rafferty 1996) often described an Ozark flora in 1818 that was different from that which exists today. This literary snapshot in time is often taken to be a static, pre-European flora. More likely, however, Schoolcraft was witness to a relatively recent, although not unprecedented, dynamic phase of Ozark vegetation that was the legacy of an Eastern Native American migration and design that preceded his visit by nearly 50 years. Here, we use climate and fire data to support the hypothesis that there was intentional burning and severe fires during drought years from 1760 to 1820.

A correlation analysis of fire scar data and a drought proxy, shortleaf pine ring width, demonstrates that fire-climate relationships are tempered by the temporal and spatial frequency of human ignitions. The Shannon County shortleaf pine ring-width chronology (Guyette 1996) is correlated ($r = 0.54$, $p<0.01$) with the Palmer Drought Severity Index (PDSI) (Cook et al. 1999). The temporal and spatial frequencies of human ignitions are particularly important factors of an anthropogenic fire regime in highly dissected terrain where the spread of fire is inhibited by topographic roughness. Between 1760 and 1820, significant correlations among the percent of trees scarred and drought (as expressed by pine ring width) indicate that climate may have been a factor directly influencing fire size and intensity (Table 6). However, this indication is not supported by correlation among drought proxies and the percent of trees scarred are weak during other periods. An alternative theory is that drought may have motivated or been a necessary condition for the deliberate burning of vegetation by Native Americans wanting to manipulate the environment to their advantage. Hunters frequenting the site during the dormant season may have cultured the vegetation of the ecosystem using fire for the purpose of improving pasture for large herbivores. Anthropogenic causes for the climate-fire correlations also explain the lack of significant climate-fire correlations after 1820. After 1820, the importance of climate as an influence on fire size and intensity diminished as fuel loading became limited by the increased frequency of fires ignited by a growing population of Euro-Americans. In contrast to a sparse population of Native Americans who burned during droughts, the Euro-American settlers burned vegetation under much less severe climatic conditions. This is consistent with the weak fire-climate relationships found at other Ozark fire history sites (Guyette and Dey 1997) and by others working in oak forests of the eastern United States (Sutherland 1997).

The first difference or ring-width difference (RWD) is the ring width of the fire year subtracted from the ring width of the year preceding the fire year. Significant correlations were found among first differences of pine ring width and the percent of trees scarred (Table 6). This indicates that both drought and primary production of fuels in the preceding year contribute to fire size and intensity, especially during the Transition Period. Correlations between ring width and the percent trees scarred indicate drought is a necessary but not sufficient condition for large fire events. The top 9 fire years (using percent trees scarred) during the Transition Period had an average PDSI of -1.2, indicating that drought was a factor in the large and intense fires of this period (Table 7). The percent of trees scarred in all fire years (1604-1996) is significantly correlated with the first differences of the shortleaf pine ring-width chronology. This relationship indicates that both drought within the fire year and the primary productivity (fuel loading) of the preceding year are weak but significant variables affecting the intensity and size of fires at the study site for almost 400 years.

Table 6

Correlation coefficients (r) among the ring-width of shortleaf pine (off site) and the percent of trees scarred at the Panther Cave Hollow site indicating a significant climate-fire relationship before 1820. Coefficients are given for all years and a stratified data set that includes only years in which there was evidence of a fire. The number of observations (n) and the significance (p<0.01=**, P<0.05=*) are given after each coefficient.

PERIOD	r (all years)	n	r (fire years)	n	r(first difference)	n
1631-1760	-0.07	130	0.33	17	0.01	17
1761-1820	-0.39**	60	-0.49*	22	0.57**	22
1821-1996	-0.02	175	-0.18	43	0.18	43

Logging Disturbance

Logging disturbance at the study site may have influenced the fire history statistics of the Panther Cave Hollow site. Dates of growth release from 8 oak stumps indicate that trees at this site were harvested in 1904, 1937, and 1996. Two 1904 release dates were identified from oak stumps and were likely due to a selective pine removal because of the proximity of associated pine remnants to the observed oak stumps. The 1904 release dates are coincident with the existence of logging camps located along creeks flowing into the Current River (Ponder 1989). One of these camps, “Rogers Camp,” was probably located near the confluence of Rogers Creek and the Current River (Figure 1). The 1937 harvest date is coincident with harvest dates at MOFEP Sites 3 and 4, the next closest MOFEP research sites in Euclidean distance. Fire dates at the Panther Cave Hollow site are not coincident or otherwise related to dates of logging disturbances. The first of these 2 logging dates (1904) likely consisted of select logging of highly valued shortleaf pine while the merchantable oak species were harvested during the second logging period (1937), a common order of events during Missouri’s lumber boom era (Cunningham and Hauser 1989, Stambaugh et al. 2002).

MANAGEMENT IMPLICATIONS

Fire History and Forest Succession at Panther Cave Hollow (MOFEP Site 9)

The period of most rapid response to a disturbance (or exclusion of it) is often immediately after a disturbance occurs. Suppression (exclusion) of fire at Panther Cave Hollow (MOFEP Site 9) will likely cause changes in forest development related to low intensity fire during the next few decades. While other MOFEP sites have had several decades of fire suppression, the Panther Cave Hollow site likely exhibits earlier stages of vegetation change following fire suppression (e.g. increase in fire-intolerant species, decrease in fire-tolerant species, increase in forest fuels). The development of the vegetation at Panther Cave Hollow in the absence of fire will be shaped by the removal of limiting factors imposed by frequent low intensity fires of the last 400 years.

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FIRE MANAGEMENT FOR MISSOURI SAVANNAS AND WOODLANDS

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ABSTRACT

Missouri's savannas and woodlands are fire-dependent ecosystems, and prescribed fire is essential for their management. Structuring a fire program, however, is more complex than simply deciding how often to burn or knowing what a single fire will do.

Fires are individual events, but the attributes of a savanna or woodland reflect the long-term pattern in which fires occur. This pattern is called the fire regime, and its main elements are frequency, intensity, spatial pattern, and season. Each element is a variable that has a range of possible occurrences, with a historic range of variation including average and extreme values. That range is locally influenced by the topography, geology, soils and current vegetation, climate and ignition source. Together, these factors determine the patterns of communities and species across the land.

Managers influence structure and composition by manipulating fire regimes. Their challenges include understanding the local physical conditions that dispose an area towards certain vegetation types; knowing how these physical and biological parameters influence the fire environment; and then applying a fire program that reflects the historic range of variation for that situation. We are only beginning to see the results of different kinds of fire patterns, through 15-30 year-old programs. From them, this paper describes some direct and indirect effects of prescribed burning, organized as general fire management principles for managing Missouri's savannas and woodlands.

INTRODUCTION

Missouri's resource professionals have been managing woodland natural communities for nearly 30 years. Their fundamental objective has been to restore or maintain the open understory and native ground-layer vegetation reminiscent of the early historic (i.e. "native") condition. Although there are many variations corresponding to different geology, landform, historic vegetation associations, and 20th century site histories, fire is always a key determinant. This paper explores the role that prescribed fire plays based on results from restoration projects since 1983.

Missouri's savannas and woodlands were historically open, with canopies of fire-tolerant and light-dependent trees, modest or sparse understories and strong herbaceous-to- shrubby ground layers. They were fire-dependent natural communities. Many contemporary upland forests are remnant woodlands and savannas, transformed by timber exploitation, prolonged open-range grazing, substantial soil erosion and loss, and frequent burning, followed by several decades of fire protection. The present-day versions have closed tree canopies with one or more understory tree layers, a robust shrub and sapling layer, and a sparse herbaceous ground layer. Virtually no woodland or savanna survived the resource exploitation to conservation eras with its open "grassy" character intact or even readily apparent.

Woodland and savanna restoration programs are aimed at reversing the impacts of recent land use history by reopening the midstory tree layer and encouraging redevelopment of the native ground-layer vegetation. Whether for restoration or long-term management, prescribed fire is the principle tool. To use fire successfully, it is important to understand how it works.

FIRE MECHANISMS

Fire does three important things that relate to planning prescribed burns for savannas and woodlands. Fundamentally, fire opens these systems to light**.** (Figure 1) It does so by causing a scorch height and understory (sometimes overstory) tree mortality that lets more sunlight reach the ground vegetation. It also reduces or removes leaf litter and standing thatch from previous years, which lets that light reach the ground. These effects are often the first-order objectives in prescribed burn plans. The degree to which fire opens the system to light is a function of the number of times the area burns, conditions at the time of each burn, and other attributes of the fire regime. Part can also be attributed to the different tolerances that woody species have to heat.

By opening the understory to more light, fire promotes plant growth. This is particularly true of ground-layer grasses, forbs, sedges, and shrubs. It also facilitates regeneration of light-dependent/fire-tolerant tree species such as shortleaf pine and the oaks.

Fire stimulates diversity and variety. Fire effects are diverse across space and time because average fuel conditions are determined by physical features like geology, soils, slope position and aspect, and influenced by season and existing vegetation patterns. Through interaction between microsite conditions and different fire tolerances (or responses) by species, fire prompts heterogeneity in local and regional plant communities.

Figure 1
Fire line at Ha Ha Tonka State Park. The area on the right has been burned 10 times in 20 years, compared to the left side, which is unburned in park history.

FIRE EFFECTS

There are observable patterns in fire responses, which managers shape into program objectives. With prescribed fire being the management input, outcomes include: a) the immediate direct effects; and b) the indirect effects over short, intermediate and long-time scales.

Starting with a typical modern woodland of multiple tree layers and limited ground vegetation, the immediate direct effects of fire include the following: Open the understory tree layer; top-kill and reduce competition from saplings, tree sprouts and shrubs; and remove litter and thatch from the ground layer. Indirectly over the short term, this increases herbaceous biomass, stimulates growth and reproduction in ground-layer plants, increases species richness, and increases the abundance of conservative species (those that still occur). Multiple fires through several years sustain an open understory with strong herbaceous/shrub growth, and influence dominance patterns and dynamics at all strata. Over the long-term, continued fire magnifies landscape-level community diversity and the complexity of regional vegetation – quite the opposite of long-term fire exclusion. Depending on the characteristics of the fire regime and the constraints placed on it by the physical environment, repeated fires might either maintain the existing community or cause transition to an even more open natural community type. Evidence for both responses may be found in some of our long-term projects.

FIRE REGIMES

Unlike the geologic, topographic or climatic factors that remain fairly constant through moderate to very long- time scales (by human standards), fire is a discrete event that stresses the physical and biological environment by destroying biomass and altering resource availability (Pickett, S.T.A. and P.S. White 1985). But for prairies, savannas and woodlands, it is also repetitive and frequent, according to our management experience and other evidence (Ladd 1991, Nigh 1992, Guyette 2000). Our vegetation patterns have been in place for the last few thousand years (Delcourt, Delcourt and Smith 1983, Smith 1980), and throughout this long time, fires shaped community dynamics as if they were a chronic disturbance. Over the long term, fire periodicity and other temporal parameters were -- and continue to be -- much more important than the effects of a single fire. The significant point for those who work with savannas and woodlands is to think in terms of fire patterns, rather than fires as discontinuous independent events.

This pattern of fire across space and time is known as the fire regime. Through it and within limits set by the local environment, managers exert the range of control that achieves their restoration or management objectives. Fire regimes have four main elements: frequency, intensity, spatial coverage, and season. Each element is a variable, which to some extent may change or be altered independent of other variables, and give a different result. Each variable operates within a range, characterized by both the average and extreme events. For example, the historic fire regime for a dry chert woodland might be described by “moderately intense surface fires every 2-5 years in spring or fall covering tens to hundreds of acres, with infrequent high-intensity fires covering hundreds to thousands of acres.” These fire regime elements are explored below.

Fire Frequency

Fire frequency may be considered from 2 perspectives: how many times an area has burned, and its burning interval. With respect to the former, Figure 2 compares an area that was burned once with 2 other areas on the same ridge that were burned 4 and 9 times, respectively. As the pictures were selected to represent, fire effects reflect the number of times an area has burned. The first few times (Figure 2a), an area will often respond with thin localized herbaceous growth, a lot of bare ground and a robust shrub and woody sprout growth. This shrub and sprout dominated phase may last 4 or more burn cycles, before the herbaceous community begins to assume dominance (Figure 2b). Figure 2c typifies areas burned many times, 9 in this case. It shows an obvious herbaceous understory, a strong shrub layer only partly dominated by woody sprouts, and an open midstory tree layer. It often takes at least 4 fires before such a ground cover starts to develop.

Figure 2a
Sparse ground cover after one fire.
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Figure 2b
Forbs and sprouts dominate a nearby area after four fires.

Figure 2c
Rich grasses, forbs and sprouts dominate another area after 7 fires.

A different aspect of fire frequency is the interval at which an area burns. As illustrated by Figure 3, areas burned at long intervals of once every several years (especially new project sites or those thick with understory trees) tend to have sparse ground vegetation dominated by woody sprouts the first post-burn year (Figure 3a) that grow taller each post-burn year (Figure 3b). Often, the understory trees survive, simply exhibiting a scorch height that corresponds to the most intense recent heat envelope. If a very hot fire or mechanical thinning removes the understory trees, the sprout layer rebounds even more vigorously. In both cases, if managed with long-interval burns, the herbaceous layer develops slowly or not at all. Such sites better mimic large canopy gaps or the woody release following a forest thinning than they do a herbaceous woodland or savanna.

Figure 3

Figures 3a and 3b
St. Joe State Park

Areas burned at intermediate intervals with fires every 4 to 6 years, (except in early stages before they recover the ground-layer vegetation) alternate between herbaceous or shrub/sprout dominance depending on where they are in the burn cycle. Species richness is high and fairly constant for restored areas, but the understory structure changes each year between burns. Figure 4a shows a typical first year post-burn presenting an open, grassy and forb-rich woodland compared to the brushy or shrubby structure they acquire before the next fire (Figure 4b). The complete mix of herbs, shrubs and woody plants is present each year, but dominance by herbaceous versus woody is a function of years since the last burn.

Figure 4a
Diverse woodland at St. Joe State Park the summer after a fire.

Figure 4b
A nearby woodland, also diverse but 3 years after the last fire.

Areas burned at short intervals (Figure 5) with annual or near-annual fires typically are strong in grasses, sedges, and forbs. For savannas, this includes warm- season grasses and species that are often associated with tallgrass prairies or rocky glades. But for woodlands, short-interval burning yields forb-rich ground layers that include shrubs, sedges and warm- and cool-season grasses characteristic of semi-shaded environments. In both cases, the understory tree layer is sparse, heavily weighted towards thick-barked fire-tolerant and light-dependent species, including shortleaf pine, black hickory and the white oak group. Because they burn frequently, the sprout and shrub layer does not get a chance to grow tall or robust even though it retains a significant presence among the ground-layer flora.

Figure 5
Open and grassy pine-oak woodland at St. Joe State Park, which is burned almost annually.

For all burn intervals, restoration and management projects demonstrate that understory structure is both dynamic and heavily influenced by fire frequency. Our most species-rich natural area examples show progressions from strongly herbaceous to shrubby with more pronounced woody vertical structure during successive post-burn years. Such cycles are strongly linked to fire frequency and seem to be a natural feature of our savannas and woodlands.

Fire Intensity

The intensity at which fires burn is largely influenced by the weather, fuel conditions, and season of the fire, things that may be selected by a manager but not directly controlled. For any large area, there is tremendous local variation in intensity based on topography and vegetation patterns because these determine the local weather and fuel conditions. Such influences are relatively fixed on the landscape and cumulative through time. They are an example of how topography, soils and current vegetation shape fire characteristics (see Fire Environment).

But fire intensity is also a function of ignition pattern. The commonly applied ring-head fire creates a convection column designed to pull fire into the center of the unit. Under unstable atmospheric conditions typical in spring, and also when the ignition circles a knob or ridge, this effect can be quite strong and magnify the heat output. Managers sometimes take advantage of this effect to maximize scorch height and mortality of understory trees. It is especially useful early in a restoration process, taking advantage of thick surface fuel accumulations. It can even prompt the transition to more open community types, and there are examples of this type of fire causing mortality of large canopy trees, particularly forests dominated by red oaks, shagbark hickories and maples (Figure 6).

Figure 6
Proffit Mountain, the year after an intense prescribed burn removed many of the overstory trees.

Intense convection-driven prescribed fires might mimic the extreme events in the long-term natural fire regime – the ones that caused major ecosystem shifts and redirected successional processes – but they are not likely to be those that sustained the systems over the long term. Probably more normal for native woodlands and savannas were long single-fire fronts, backing or flanking fires, and fires under more stable atmospheres and less severe moisture conditions. These conditions happen many times every year, intermittently through every season, providing many times that fuels are receptive to the largely human sources from which these fires derived. Fires conducted in milder weather conditions or when a portion of the fuel is green are less intense and cause different results over the short and long term. Still, these milder burns perform most functions– including top kill woody sprouts, remove surface litter and thatch, and stimulate the ground vegetation – that are normal and natural for long-term maintenance of a savanna or woodland ecosystem.

Fire season

Although spring fires have been a management tradition, historical accounts and fuel patterns suggest that fire occurred, perhaps frequently, at other seasons of the year. Summer is when most lightning fires occur on the central plains; late summer and fall is when history tells us that most Indian-set fires would have been set (Higgins 1986, McClain and Elzinga 1994, Howe 1994, and Moore 1972). Humans and lightning were the dominant fire source for Missouri savannas and woodlands throughout most of their post-Pleistocene history, with dendrochronological evidence (Guyette 2000) indicating that human ignitions were very prevalent in our area.

The effects from growing season fires are much different from spring fires (McCarty et al.1995). Most fire-managed woodland communities, which depend on leaf litter to carry the fire, are not particularly flammable in summer or early fall except under abnormally dry conditions. The canopy and landscape position often shelters them from wind, the humidity tends to remain high, and the green herbaceous/shrub/sprout layer forms a vapor barrier that impedes or suppresses fire spread.

But open savannas, glades, and prairies with warm-season grasses to carry the fire burn readily in summer and fall, and burn windows generally span multiple consecutive days (consider the long dry, days of Indian summer). Fire behavior characteristics change from the volatile days of spring, and effects on woody and herbaceous plant growth are markedly different. For example, fire spread rates are much slower, yet the fires will affect much larger trees. This includes those that have survived previous dormant-season or early spring burns (Figure 7). Late summer and fall burns often leave the coarser stems of herbaceous plants standing, and are much more likely to leave patches and areas unburned or lightly burned compared to spring or winter fires. Because the plants are in different stages of their growth cycle, indirect effects vary, too. There is often a post-burn green up before frost, where forbs, sedges and cool-season grasses redevelop, and a much earlier spring green up. Flowering responses are usually greater the following year as well for many of the characteristic plants.

Figure 7
Long Branch State Park, where all the trees in the photo were browned out by a late summer prescribed fire through the adjacent prairie. The larger oaks produced new leaves the following year.

Fire spatial pattern

Fire regimes are also characterized by the size and shape of the burns on the landscape. In early historic and prehistoric times, this might have reflected the fuel characteristics of adjacent community types; local landform; ignition source and location; the season in which fires tended to occur; proximity to human settlements or travel routes; and the presence of major fire breaks such as rivers. For example, rates of fuel accumulation can influence spatial pattern for frequently burned areas, where different fuel types may not burn as readily as adjacent ones under low-fuel, seasonally moist or green-fuel conditions.

Most modern woodlands are too small to have topographic features or daily weather patterns limit their size. Prescribed fires are usually designed to burn completely within a single day's weather window. Thus, fire pattern at the scale of modern management areas often reflects the size and shape of workable burn units, and area-wide variety is created by the number and configuration of units recently burned. This may be different from the landscape-scale patterns that prehistoric vegetation associations would have induced.

There has been a trend to increase the size of the burn unit to several hundred or more than a thousand acres so that landscape features and variety in fuel types or conditions can create a spatial burn pattern that reflects these natural influences on fire behavior. This more closely mimics a natural fire regime, compared to convective-driven fires set on small units on the most favorable burn days.

Average versus extremes

Each fire regime variable operates within a range, characterized by the average and extreme events. Both are significant. Earlier we described an average fire for a dry chert woodland occurring in spring or fall and being moderately intense, with 3 to 5 year return intervals. A prescribed fire program that always replicates this "average" fire might be entirely adequate to sustain a particular expression of open grassy/forb woodland where all that is needed is periodically top-killing sprouts and removing litter and thatch. One that regularly mimics the extreme events of either very wet or dry times might instead prompt transition to a different community type. Each lies within the historic range of natural variation, but if the imposed fire regime emphasizes just one set of parameters, it might not produce the same landscape-scale variability that was inherent in the natural models. Managers consider the different roles that average and extreme events played when they structure fire regimes for an area.

FIRE ENVIRONMENT

Fire behavior is a function of the interaction between fuel, topography, and weather. Fire ecologists call this the fire environment. Certain patterns characterize a locale or region, and emphasize the importance of the landscape context. For even if the incidence of fire remains the same for a broad region, the fire regime for different locations within it will vary because different terrain, aspects, slope positions, soil moisture characteristics, and the vegetation patterns that they favor create vastly different fire environments on very fine scales.

As an example, a riparian woodland (Figure 8) offers a much different fire environment than the dry upland woodlands and glades that might surround it. They are embedded within one another, yet their fire regimes differ even though they are exposed to the same fire frequency.

On the landscape scale, the high prairie plains of the early historic Ozarks were well exposed to sun and wind. Their fuels dried quickly; there were few barriers to fire spread; and their vegetation was highly flammable. Fires were frequent, burning fast and hot across long spaces. But flanking each prairie plain lay dissected hills with many complex slopes leading down to the river valleys. These were covered in woodlands that were more sheltered and shaded, had lower average temperatures and wind speeds, higher average humidity and fuel moisture, and much less flashy fuel with multiple barriers to fire spread. Their fire regime was different from nearby prairies or savannas because the fire environment was less conducive. An example of what this means is that there was probably no prairie-like regime of frequent hot fires on north slopes deep within major river watersheds, nor should we expect an open prairie to develop there through prescribed fire because neither the physical environment nor the historic vegetation supports it. An applied prescribed fire regime needs to match the situation, and while one easily observes that a fire regime shapes the plant community, it is equally true that this plant community's structure and composition sets some of the limits for a fire regime.

To extend this thought, fire-prone natural communities once served as ignition sources for less flammable ones, causing fire frequencies to be greater than they otherwise would be or modern wildfire statistics reflect. Open prairies and savannas covered over one-third of Missouri, spanning the watershed divides and broad river floodplains. They burned frequently and spread fire into vegetation types where ignition from within was less likely. Flatwoods are examples of natural communities that probably burned more frequently because they occurred near prairies or savannas. Many of the swamps and bottomland hardwood forests of our southeast lowlands would have burned during dry years and seasons for the same reason. And woodlands throughout Missouri probably burned more often from fires spreading into them from nearby prairies or savannas than they did from fires ignited within. Thus, the presettlement fire frequency that modern land managers strive to match may be better predicted from the surrounding landform and its historic vegetation than the fuel characteristics strictly inside either the modern or historic woods.

Figure 8
A small riparian zone, lying within a savanna management unit at Ha Ha Tonka State Park that has been burned 9 times in the last 30 years.

CONCLUSION

Goals for prescribed fire programs emphasize open, light rich herbaceous environments beneath high canopies of light-dependent and fire-tolerant tree species. Objectives anticipate plant compositions that mirror the native natural predecessors, and seek diversity across different substrates, landforms, and microsites. Strategies involve fire as a natural process integral to dynamic vegetation patterns, synergistic with other elements of the physical and biotic environment.

Historical records, dendrochronology, understanding the ecology of native flora and fauna, and a knowledge of fire behavior helped guide the first restoration and management efforts. Unlike when the fire programs were started 30 years ago, Missouri now has a few hundred thousand acres of public land undergoing fire management, with several natural area examples that clearly show how fire influences these natural communities. Learning more about what the historic fire regimes might have been – and projecting future prescribed fire regimes for them – will rely heavily on observing responses from continued burning in our restored remnants.

An important lesson from the current efforts is that frequent fire has been important in restoring all varieties of savannas and woodlands. Composition and structural differences between community types strongly reflect local landform, geology, soils, and existing vegetation, which all influence the fire regime. There is clearly an association between the fire behavior that created or maintains savannas and woodlands and the physical and biological environment from which that fire behavior derives. We have also seen that savannas and woodlands are spatially complex and temporally diverse, with a structure that naturally oscillates between burn cycles yet always possesses a richness of species and community associations.

Whatever the late Holocene history of a site may have been, its present condition also reflects modern events and its future will develop according to an applied fire regime. Without fire, savannas and woodlands will be lost. With fire, how well they are preserved depends on whether we can restore the physical conditions that support them, reverse historic damage, and replicate the natural fire regime. Except as intensified during early restoration phases, this should mimic the historic range of natural variation and certainly support the diversity of native plant and animal life associated with them. It should also allow for the spatial and temporal dynamics of these robust natural communities.

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MANAGEMENT EFFECTS ON THE HERBACEOUS VEGETATION OF AN OAK-HICKORY SAVANNA RESTORATION

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ABSTRACT

Clearfork Savanna is located in Knob Noster State Park, Johnson County, Missouri and has recently been managed by the Missouri Department of Natural Resources to restore it to the original Oak-Hickory Savanna condition. Transects were established in a control area as well as two different treatment areas in both 1992 and 2000 with species composition and cover data collected. In one treatment area only burning has taken place whereas the other burning and selective thinning have been the management strategies. Cluster analysis was used to classify communities. These results showed that the 2000 data set had community structure related more strongly to treatment areas as compared to the 1992 data set. Detrended Correspondence Analysis (DCA) was performed on data from 1992 and 2000 separately and this showed separation of the different management treatments with control on one side and the burned and thinned on the other with the burned transects only as an intermediate. Species with high and low coefficients of conservatism were also plotted on the 2000 DCA graph showing relative species abundance within each transect. This showed that the species with the high coefficient values were primarily in the burned and thinned treatment areas whereas the species with the low coefficient values were shown to occur with in control and burned only transects. The inability to relocate any of the 1992 transects and different timing of sampling limit the ability to see community change over the eight year interval of the study.

INTRODUCTION

The restoration of pre-settlement vegetation is a major focus of many natural area biologists e.g., (Noss 1985, Becknell and Journet 1991). Efforts have been especially important in the preservation, management and restoration of natural communities such as prairies and savannas (Neely and Heister 1987). Fire is often an important part of these management plans (White 1986). A fire regime strongly influences structure and composition of savannas, with increasing fire frequency reducing canopy cover and limiting oak recruitment (Faber-Langendoen and Davis 1995).

The oak savanna plant community is described as fire-dependent grassland with scattered individual trees (Curtis 1959, Eiten 1986). Savanna is thought to be physiognomically a transitional community between prairie and forest (Nuzzo 1986), and is particularly susceptible to any disturbances that may occur on its borders. The appearance and composition of savanna communities are governed by the frequency of these disturbances (Abrams 1992). The presence of fire and/or dry conditions results in a shift toward a prairie-like condition while the absence of fire and presence of moist conditions results in a closed canopy forest (Hruska and Ebinger

1995).

Oak savannas were once an important part of the landscape in the Mid-west but are becoming quite rare. Only about 0.02% of original savanna is left of the estimated 13 million ha (Nuzzo 1986). In Missouri, savannas consist of a mixture of primarily oak species, but also hickory, pine, and other mixed hardwoods and an over story coverage between 10-50% (Nelson 1985). Most of the savanna has been cleared for cropland, converted to pasture or changed through succession due to fire suppression permitting the growth of trees and shrubs forming closed canopies and eliminating the shade intolerant prairie species from the under story e.g., (Auclair 1976, Bowles and McBride 1998). Today, only a few high quality savannas remain in the Midwest (Nuzzo 1986). In Missouri State Parks, there are 23 locations in which degraded savanna habitats have been recognized. These areas are currently being managed to restore them back to their original state (Leach and Ross 1995). Clearfork Savanna, Knob Noster State Park, Johnson County, Missouri is one of these remnant savannas under restoration.

STUDY AREA

The study site is located within the Clearfork Upland Savanna Area of Knob Noster State Park, S29 T46N R26W, Johnson County, Missouri. Clearfork Savanna is a 123 ha area that has been under the management of Missouri Department of Natural Resources (MDNR) since the early 1980's. Prescribed burns of portions of the area were conducted in the springs of 1982 and 1985. The entire management area was burned nine times in the winters and springs starting in 1988. The most recent prescribed burn was November 17, 1998. Selective tree removal has also occurred on 23 acres in 1983, 18 acres in 1985 and 13 acres in 1989 (T. Ramsey, Missouri Department of Natural Resources, Personal Communication). The area is transversed by a 1 mile hiking trail open to public use. Plots were established in 1992 by Ken McCarty, MDNR but could not be relocated in 2000. Plots in 2000 were placed in the same treatment areas and control area as the previous study. Prior to government acquisition in 1934 the integrity of the plant communities in Knob Noster State Park was strongly compromised due to mining and clearing of trees. Since the acquisition of the park the Missouri Department of Natural Resources has been responsible for its management.

METHODS

Within each of the two treatment areas and the control area, four 50-meter transects were established. Transects ran perpendicular to the slope and marked at both ends with two pieces of rebar approximately 14 cm long. Aspect, slope and GPS coordinates in UTM were recorded for each transect. Plot placement followed transect method described by Kershaw and Looney (1985) in which quadrant samples are taken along each transect at known intervals. A 1/4 m^2 square was used as the quadrant for all samples. The square was placed on the ground perpendicular to, and to the left of, the transect line starting at 5 meters and then every five meters thereafter yielding 10 samples per transect. Every species within each of the quadrants was then identified, counted and recorded. Each species was assigned a cover class by estimating percent cover within the quadrant. Coefficients of Conservatism were assigned to each species following MDRN rankings. They ranged from 0-10 with higher numbers indicating plants most likely to occur in a landscape that is relatively unaltered from a pre-settlement condition (Penskar *et al*. 1996).

Cluster Analysis using Importance Values was used to classify the transects into community groups based on their species composition using Importance Values. The Importance Values (IV) for each species was calculated by taking the relative density of the species plus the relative cover within each transect.

Detrended Correspondence Analysis (DCA) was used to ordinate transects using Importance Values. Rare species were down-weighted and any species occurring only once within any transect was eliminated to reduce distortion. Comparisons of transects between the two years were not done due to somewhat different species composition caused by the timing of sampling. (The 1992 was collected in May and the 2000 data in August.)

The DCA ordination of 2000 plots were used to visually represent abundances in 2000 of individual species. The species with the highest Coefficients of Conservatism and typical of prairies, list, were chosen as well as common species most indicative of the woodland conditions of the control transects, all of which have low coefficients, *Desmodium glutinosum*, *Parthenocissus quinquefolia*, *Prunus serotina*, and *Polygonum virginianum*. Plant nomenclature follows Steyermark (1963).

RESULTS

The cluster analysis (Figure 1) failed to show distinct communities in the 1992 data set. However, the cluster analysis of the 2000 transects showed that treatments were more differentiated from the control, but not from each other.

In both 1992 and 2000, DCA analysis showed separation of the control, burned only, and burned and thinned transects (Figure 2). In both years, the control and the burned and the thinned showed the most distant ordination. Ordination of the 2000 transects accounted for a higher percentage of variance explained than did the 1992 transects on both the first and second axes. The eigenvalues for the 2000 transects were 0.493 and 0.190 and the first and second axes respectively while the 1992 eigenvalues were 0.327 and 0.077 respectively.

Species with high Coefficients of Conservatism were largely restricted to occur largely in the burned and thinned area (Figure 3). The abundant woodland species were also common in several treatment transects but in a unique pattern for each species (Figure 4). The two transects in the burned and thinned area were most extreme with a concentration of prairie species as well as the lack of the common woodland species.

Cluster Analysis

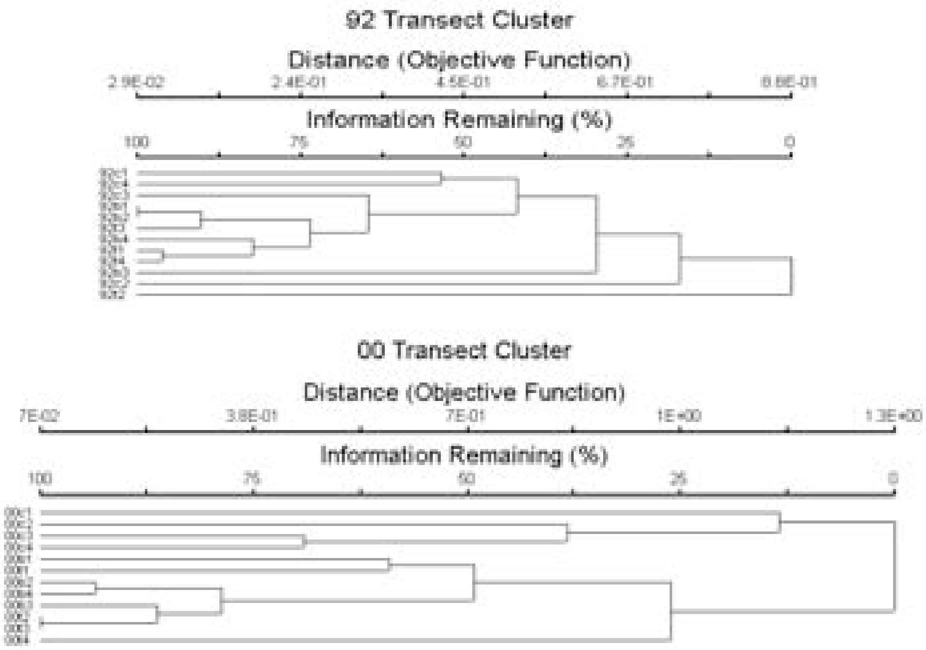

Figure 1

Cluster Analysis of 1992 (45 species, 12 transects) and 2000 (51 species, 12 transects) data sets of Clearfork Savanna. Groupings of similar transects are based on species composition using Importance Values (relative cover + relative frequency). Transects were equally divided among control (c), burned only (b), and burned and thinned (t) treatment

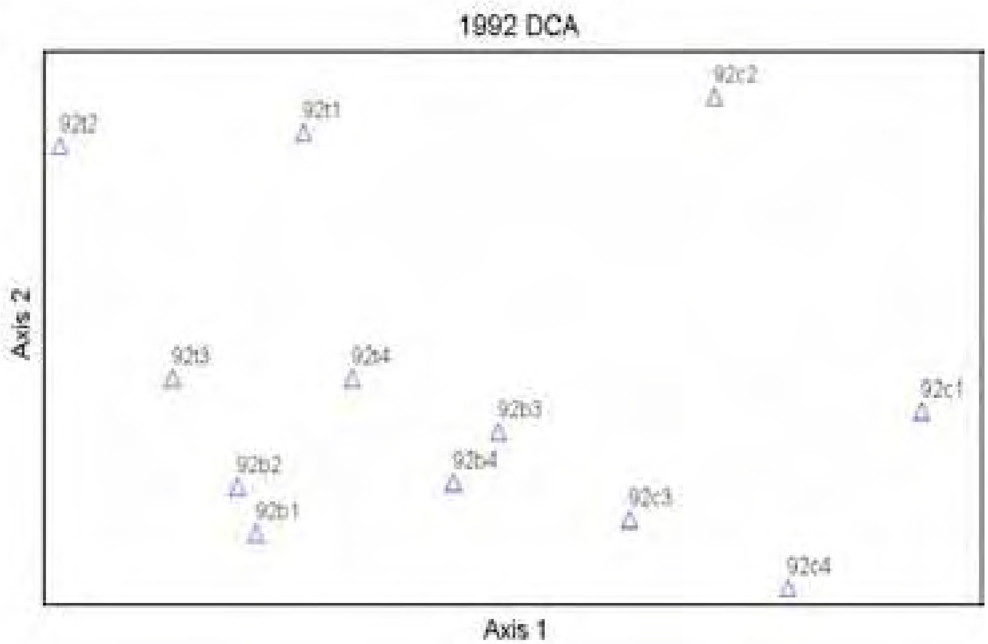

Figure 2

Detrended Correspondence Analysis (DCA) for 1992 (45 species, 12 transects) and 2000 (51 species, 12 transects) data sets of Clearfork Savanna. Sample transects are represented by points in the diagram. Samples are placed along axes representing hypothetical environmental gradients based on their species composition using Importance Values (IV). Samples with similar species composition lie closer together. Lines separate transects from different

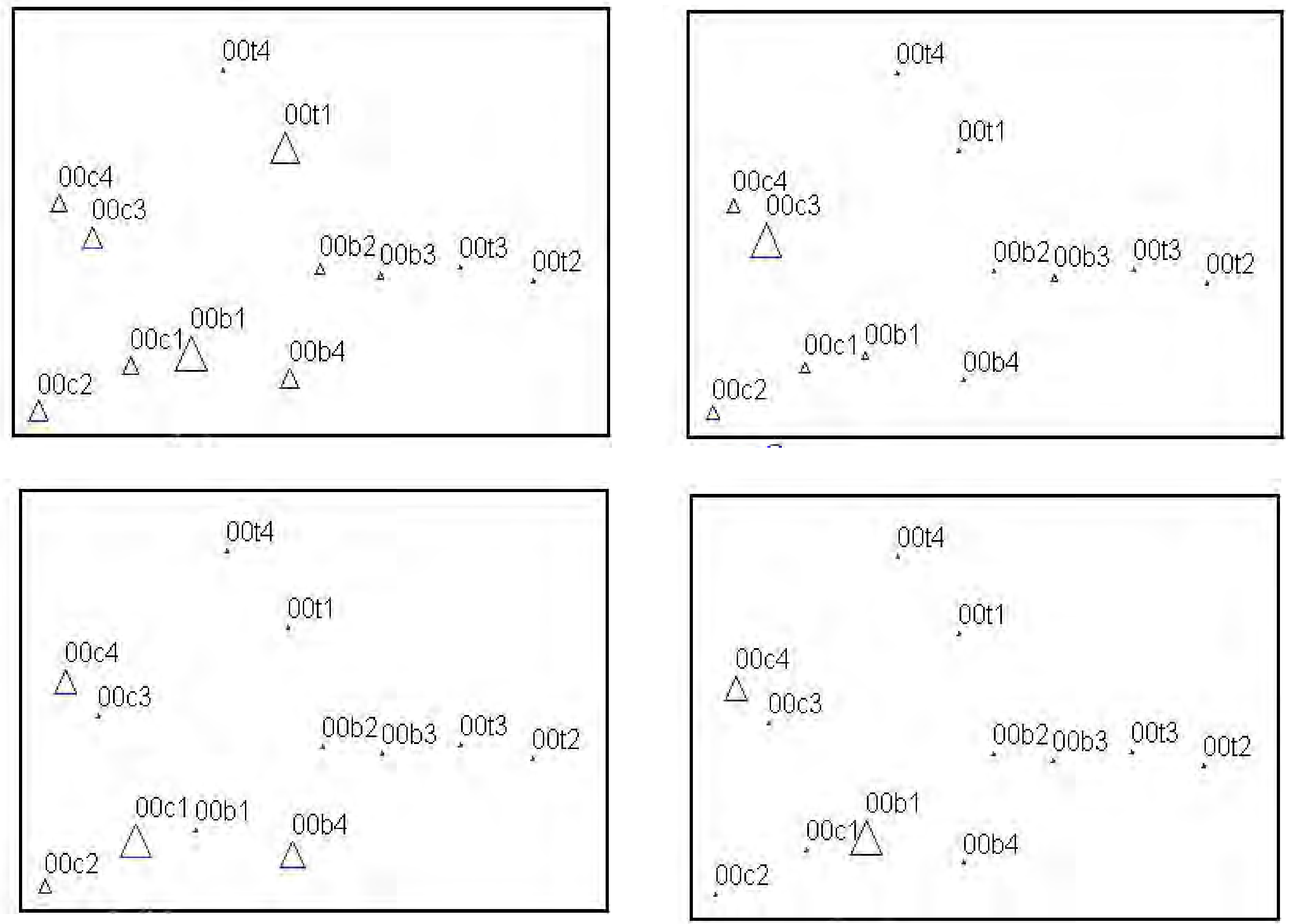

Figure 3

Graphs from DCA ordination of 2000 transects showing relative species abundance represented by size of symbol within each transect. Species shown are *Desmodium glutinosum* (A); *Parthenocissus quinquefolia* (B); *Prunus serotina* (C); and *Polygonum virginianum* (D). All species shown have coefficients of conservatism of ≤ 3. Coefficients of conservatism are: A=3, B=3, C=2, D=1

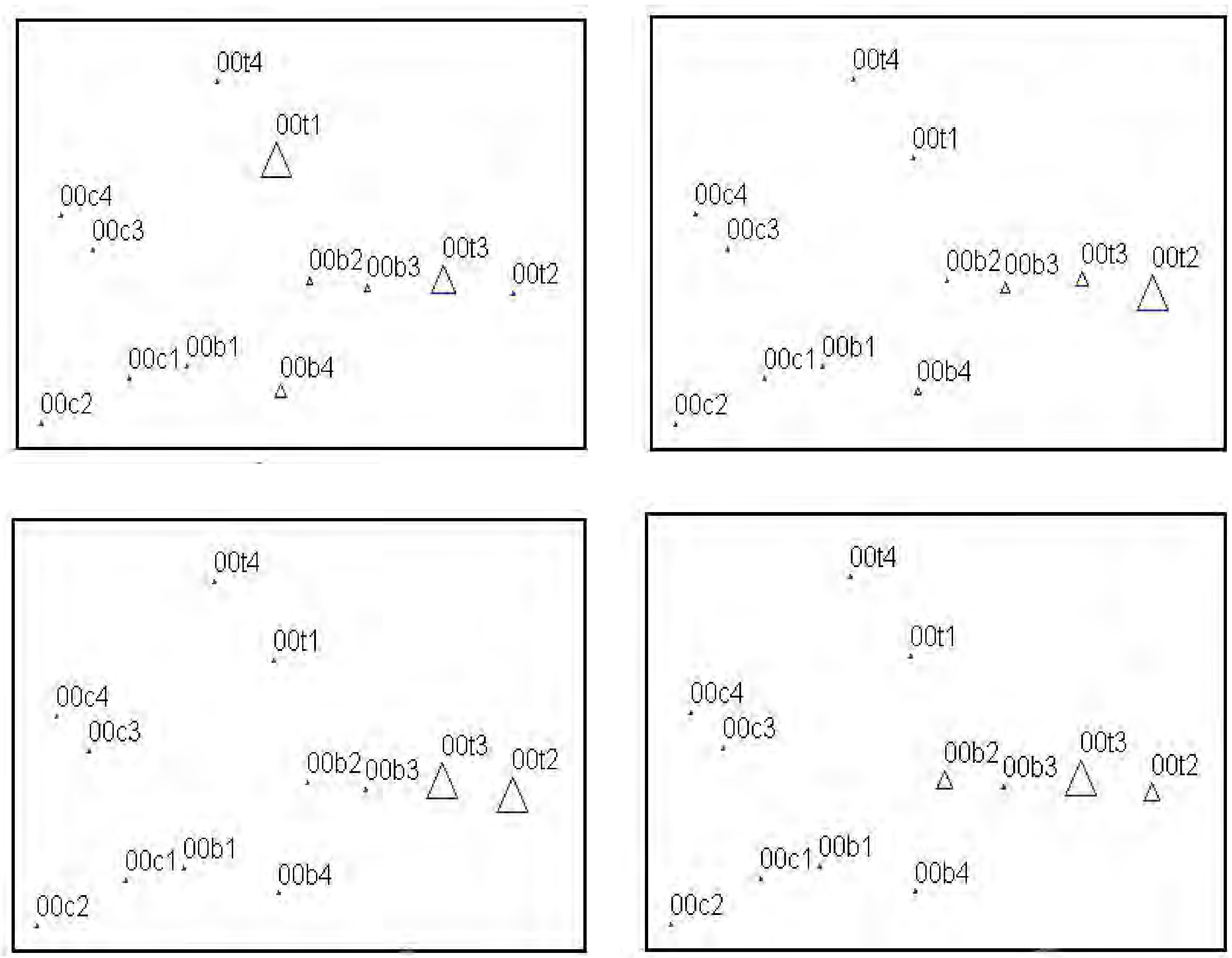

Figure 4

Graph from DCA ordination of 2000 transects showing relative species abundance represented by size of symbol within each transect. Species shown are *Helianthus hirsutus* (A); *Antennaria plantiginifolia* (B); *Liatris squarrosa* (C); and *Aster turbinellus* (D). All species have coefficients of conservatism of ≥ 4. Coeffiencients of conservatism are: A=4, B=5, C=5, D=6

DISCUSSION

Cluster analysis gives indication that the treatment areas have become more dissimilar in the eight years between the samplings. The two treatments could not be distinguished from each other in either year. However, DCA indicated consistent difference in both 1992 and 2000. The DCA outputs are similar in the distribution of plots except for a “mirror” effect on the X-axis that is an artifact of the computer program.

MANAGEMENT IMPLICATIONS

The present study lays a foundation for future rigorous evaluation of savanna treatment methods. The present study indicated that the herbaceous-layer vegetation of the treatment and control areas were different and that the differences were more pronounced in 2000 than in 1992. Portions of the burned and thinned area matched closely the expectations of a savanna with prairie forbs and grasses herb-layer with scattered oaks and hickories. Future sampling will address more directly if the prairie vegetation is spreading beyond its current extent and if typical woodland species decline in the treatment areas.

Caution should be used in comparisons between years in the present study since different specific transects were sampled and because sampling was conducted at a different time of year, May versus August. It is not possible to ascribe all difference between control and treatment areas to management techniques since the 1992 sampling was done nearly a decade after the first controlled burn. The decision on the location for the savanna restoration was likely based on the presence of remnant prairie plants so the treatment and control areas may have differed initially.]

ACKNOWLEDGEMENTS

Ken McCarty allowed use of his unpublished 1992 data. Theresa Ramsey assisted in the long and futile attempt to relocate the 1992 transects. Daniel Metcalf assisted with field work. Funding was provided by Missouri Department of Natural Resources and the Willard North Foundation of Central Missouri State University.

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ASSESSING VEGETATION CHANGES IN RESPONSE TO FIRE MANAGEMENT IN OZARKS WOODLANDS

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ABSTRACT

An adaptive management approach to ecological restorations in Ozarks woodlands has involved: establishing measurable objectives, identifying attributes of ecological health, choosing from a variety of monitoring tools and designing a monitoring approach, implementing baseline monitoring before management treatments begin, taking action, and assessing effectiveness with follow-up monitoring so management can achieve the best possible results. Effects of fire management are often erratic and have complex relationships to environmental variables. Differing past land use and management histories can make following cookbook recipes for restoration problematic. All restoration efforts should use some type of monitoring, from simple and cheap to complex and expensive, to know and document whether management is actually achieving desired results.

INTRODUCTION

The Nature Conservancy is a not-for profit conservation organization established in the United States in 1951. With a mission focus of biodiversity conservation, the Conservancy has worked successfully to identify and acquire lands protecting imperiled plants, animals, and significant natural habitats. Over 50 years of this work has created the largest network of privately owned and managed nature preserves in the world.

In Missouri, the Conservancy has been managing to restore woodland and savanna habitats using prescribed fire management for over 15 years. Defining and measuring success in these restoration efforts without imposing arbitrary quantified target conditions to the sites has presented challenges that are overcome by using an adaptive management approach. A significant part of this approach involves establishing a good system of monitoring changes and using that information to modify management to efficiently achieve the best possible results.

GOALS: WHAT DO WE WANT?

Broad goals for management of Ozarks woodland and savanna sites vary greatly between landowners. A private nature preserve or designated state natural area may want a diverse and ecologically sustainable assemblage of natural communities. A state or federal conservation area may want to maximize habitat for a suite of game species such as deer, turkey, or quail. Other conservation areas may want to maximize habitat characteristics for specific declining or imperiled species. Private landowners may want to maximize outputs of forage or wood fiber in a context of native vegetation cover. And most commonly, public and private managers want a combination of wood or forage production, wildlife habitat, and some natural character to their area. Since objectives for these different goals are not always entirely compatible, it is useful to identify major goals and the proportional importance of each before defining specific management objectives.

ATTRIBUTES OF A HEALTHY WOODLAND/SAVANNA

Establishing management objectives for an ecological restoration in an Ozarks savanna or woodland requires knowing some description of an ecologically healthy condition. Information from historic vegetation studies, studies of dendrochronology and fire histories, and examination of high quality remnant natural communities give us a rough idea:

1. Tree canopy of pine, pine-oak, or oak,
2. Minimal midstory of trees and shrub species,
3. Well-developed ground flora with a high diversity of grasses, sedges, and forbs (especially legumes and composites), and
4. Frequent surface fire maintaining tree structure and ground layer diversity.

IS MANAGEMENT WORKING?

How do we know if restoration activities are achieving desired results? All too often this is determined subjectively by managers through regular “walk through” observations of changes at a site. The shortcomings of this approach often includes the lack of documentation left to future managers, subtle changes and differences that are missed, and a tendency to focus on gross changes in vegetation structure and a relatively few showy or unique herbaceous species. The advantage of this approach is simplicity and the ability of a manager to become intimately familiar with the variation and nuances of the site. If managers document this “walk through” technique and combine that with other monitoring activities, an integrated monitoring approach can be designed. Other types of monitoring activities include biological inventory, systematic description, photography, quantitative measures, and applied research. By including the manager and field notes in the monitoring efforts at the site, monitoring data collection, data interpretation and management decisions are better integrated, a key aspect of the Conservancy’s adaptive management approach.

Just By Looking

This is the simplest form of monitoring and by far the dominant method used in restorations. This method can provide useful monitoring information and most importantly involve the manager with monitoring staff and data that is so often, by necessity, invested with separate individuals. Three attributes are needed to turn this “walk through” method into useful monitoring: (1) a systematic approach, (2) repeatable methods, and (3) documentation. Observations should be documented in the form of field notes that can be organized and shared with others or left for future managers. Observations should be made of the same areas from year to year and the same types of things to be able to focus the effort on noting change.

Attributes more easily observed are vegetation structure, dominant species, presence or absence of weeds or species of conservation concern, relative abundance of characteristic species, flowering and seed production, and size and gross abundance of species or vegetation cover. Things often overlooked or impossible to casually observe include subtle differences from year to year in a wide variety of attributes, subtle differences from place to place in an area, seedlings or rosettes, relative abundance of the hundreds of less than common species, root systems, and seed banks. Other monitoring techniques are better at describing these types of changes.

Biological Inventory

Biological inventories provide extremely useful information about what species are present at a site. Most often, this type of information is useful in establishing baseline conditions and informing initial management planning. The presence or absence of weed species can be very important to management objectives. The presence or absence of species of conservation concern may be equally important. The physiognomic composition within a group of species present may also be useful, i.e., a bird list may consist of wide ranging habitat generalists and be devoid of characteristic open woods species. The composition and group characteristics of a biological inventory can provide useful change data if repeated in future years.

Systematic Description

Ecologists have designed a myriad of different plot designs, line transects, and point intercept methods of describing habitat or natural communities. While most of these methods of measurement have been designed for descriptive purposes, validating classification systems or describing variation in attributes among sample sites, they are often used as monitoring plot designs by making locations permanent and repeating measurements in later years. These methods typically measure vegetation structure, age and size distributions of species or physiognomic groups, relative dominance or abundance of species, and physical properties of a site such as slope percent, aspect, soils, and geology.

Photography

Photography is a readily accessible monitoring tool that can be very powerful in documenting both management actions (fire behavior) and resulting changes. Irregular views can be useful in capturing both typical and extreme fire behavior but is less effective at documenting vegetation change. Fixed point photos can be very repeatable and when coupled with vegetation plot measurements can make interpretations of data easier to communicate. Aerial photographs and satellite imagery can also be useful but is limited in it’s ability to see through canopies to observe undergrowth and ground flora changes. Infrared aerial photography can be very useful in tracking changes in canopy composition in mixed pine and hardwood areas. Digital imaging has provided the ability to take and process large volumes of photographs at low cost. At one Conservancy site, one person can take and process in the computer 5000 fixed point images in less than 2 months of field work. Digital images of canopy conditions, looking upward, can be processed in the computer to allow very accurate measurement of changes canopy cover and light penetration.

Quantitative Measures

Changes in herbaceous composition and diversity are most effectively described using quantified methods of measurement. Small squares or rectangular sampling frames, quadrats, of various sizes are used and are arranged in regular arrays or random fashion. Depending on the richness or rank nature of the vegetation, quadrats of 0.1 square meter, 0.25 square meter, and 1 square meter are typically used. Critical to the usefulness of the data collected from quadrats is the quality and consistency of the species identifications. Generic identifications such as tick trefoil (*Desmodium spp*.) are not useful to data interpretations for ecological restoration projects. Such an identification could represent a habitat generalist such as the pointed tick trefoil (*D. glutinosum*) or a conservative species restricted to quality areas such as Nuttall's tick trefoil (*D. nuttallii*), a significant discrimination in the context of restoration success or failure. While the presence of unknown species identifications is inevitable in this kind of sampling, with botany training in field identification and quality assessment and control measures in place, the number of unknowns can be kept to low percentages with a reasonable amount of effort. The limiting factor in implementing this kind of sampling is nearly always the agency or landowner's ability to get trained botanists on the ground. Field identification of plants and animals seems to be becoming less common training in biologists graduating college. Other quantified monitoring measurements involve single species monitoring where numbers or densities of specific species of plants or animals are measured. Methods are tailored for the specific biology and habits of each species.

Experimental Research

As quantified measures are made and repeated through time, the line between monitoring to describe change related to management and applied research seems to blend insensibly. Applied research often attempts to determine cause and effect by using control treatment areas and constrain management methods such as fire frequency and patterns. Measurements are often replicated robustly to increase statistical confidence within attribute data. There are instances when this method of measuring change is needed, but typically the expense of this method is higher than all other previously described methods combined. Managers and administrators should consider carefully all options available if cost is a consideration.

ATTRIBUTES OF GOOD MONITORING

What makes data or observations useful to monitoring management success? Information should be provided in a timely fashion. If data is needed by a manager on an annual or seasonal basis, as in controlling invasive species populations, then an applied research design that requires extensive data manipulation and analysis may not be desirable. Information should be affordable. Complex and intensively replicated monitoring designs may provide high statistical confidence in results but may be more expensive to implement repeatedly than an agency or site budget can afford. Information should relate directly to the attributes most important to management objectives. While attributes like growth rates in canopy size trees may be useful information for a site interested in sustainable timber production, it may not be as useful to directing management at a site with different goals and objectives. The philosophy of “more information is better” is not as helpful in a limited budget environment as a philosophy of “the right information when it is needed.”

Regardless of monitoring techniques employed, monitoring information should be of consistent quality, use systematic and repeatable methods, and be well documented. Monitoring data is used to track changes through time. If large variation exists in quality among samples, false changes can be interpreted from the data. Changes of 2 or 3 species per quadrat in herbaceous sampling can represent significant improvement or decline in a restoration. Testing of sampling consistency among Conservancy botany crews in Missouri over the past decade has shown the difference between multi-season experienced field botanist data and data from newly trained and inexperienced field botanists can easily be greater than 2 or 3 species per quadrat. Quality controlled measures, such as pairing new botanists with experienced staff, are one practical solution. Good documentation of monitoring methods is also a necessity. Good record of plot or photo point locations, the size and shape of plots or quadrats, the units of measure (dbh in inches or centimeters), and the scientific nomenclature used will be critical to someone trying to repeat the data collection in future years.

ADAPTIVE MANAGEMENT

Adapting management to biological response is necessary in restoring Ozarks savanna and woodlands given the complex nature of fire effects and the differences in past land use and management history among sites. Three moderate intensity fires in 5 years on the south face of an igneous knob glade-savanna site will not necessarily yield the same results as 3 similar fires on the south face of the next knob over. Differences in restoration potential between sites cannot always be observed or measured prior to restoration actions. Most often this is attributed to differences in seed banks or in the amount of remnant root material not visible beneath leaf litter prior to reintroduction of fire. Herbaceous response in these restorations is highly variable. Managers need to be attuned to these differences and be able to adjust management as dictated by the site response.

The Conservancy’s adaptive management process is a simple circular, iterative, model involving defining desired results, monitoring important attributes prior to management actions and assessing condition, planning management, and taking action. The pattern of monitor-assess-plan-act is repeated on a regular cycle. Key elements to making this work are: well defined desired results, managers directly involved with a monitoring and assessment program, good monitoring in place providing the right information in a timely fashion, documentation, and a willingness to identify and share negative results as easily as positive. A method of tracking the what-when-where-how of management actions is also needed to inform management planning and future assessments.

THE RESPONSE OF SOIL STRUCTURE TO LIMING AND CONTROLLED BURNING

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INTRODUCTION

Soils are three dimensional natural resources that support plant growth, cycle carbon and other nutrients, store and transmit water, exchange energy with their surroundings, and maintain an impressive array of microbial and invertebrate populations (Brady and Weil 1996). Each soil supports and responds differently to these phenomena because of numerous inherent physical, chemical, and mineralogical properties, chief among these being pH, texture, and structure. Texture is the percentage of the sand, silt and clay fractions, coupled with visual estimates of the gravel contents (Brady and Weil 1996). Soil structure is the arrangement of the texture fractions into aggregates, which are classified by their distinctive shapes, sizes, and coherence (Kay and Angers 2000). In surface and near-surface horizons soil organic matter (SOM) is an important cementing agent that enhances aggregate coherence and provides much of the soil's cation exchange capacity (CEC) (Baldock and Nelson 2000, Brady and Weil 1996).

The purpose of this investigation is to assess the influence of controlled burning programs on soil structure and SOM levels of selected forest soils on Taum Sauk Mountain. A secondary objective is to determine the influence of liming treatments on the soil's structure and its physical and chemical attributes. Improvements in the chemical attributes of the soil should promote the post-burn regrowth and reduce the specter of soil erosion. Several soils were investigated and provided experimental data, which when interpreted gave similar conclusions regarding erosion and the effects of the controlled burning program, thus only the Knobtop soil data will be presented.

EXPERIMENTAL DESIGN, FIELD, AND LABORATORY PROTOCOLS

Two sites representing the Knobtop series (fine-silty, mixed, mesic Aquic Hapludults) were established on Taum Sauk Mountain. Typically, these soils are located on summit positions and have deep to somewhat deep, well-drained, and strongly-acid to extremely-acid profiles. The surface horizons consist of a thin O horizon (2-3 cm) composed of litter and partially burned residues (POM), partially- to fully-humified SOM, and a living, dense root-mat. The silty A and E horizons abruptly alter to a silty clay loam Bt horizon overlying unfractured rhyolite. The initial soil characteristics are listed in Table 1. Deciduous forests form a partially closed canopy cover over much of the study area, with vegetation composed mostly of white oak *(Quercus* *alba)*, northern red oak *(Quercus rubra)* and an assortment of grasses, herbaceous plants, and mosses.

Four plots were established (50 ft x 50 ft). Two of the plots were not subjected to a controlled burn and 2 sites experienced a controlled burn approximately 3 months prior to plot establishment. Secondary treatments included liming (1,742 lbs. calcitic limestone • $acre^{-1}$) 1 plot from each of the unburned and burned areas. Physical and chemical procedures are those of Carter (1993).

Table 1.

Initial soil properties at Taum Sauk Mountain immediately after imposition of liming treatments (March 1999).

Treatment	pH		Exchangeable Bases					LOI	
			Ca	Mg	K	Na	Neutralizable Acidity	O	A
	O	A	$cmol_{(p+)} \bullet kg^{-1}$					%	%
	Horizons								
			Knobtop Sites						
lime-unburned	5.8	5.3	0.96	0.29	0.13	0.15	6.7	12.4	2.5
no lime-unburned	4.0	5.7	0.47	0.25	0.12	0.14	6.3	6.4	2.9
lime-burned	5.5	5.8	1.61	0.39	0.15	0.16	6.5	7.1	2.6
no lime-burned	4.6	5.5	1.20	0.37	0.17	0.17	8.5	12.4	3.0

All values represent a composite sample taken from uniform slices of the A horizons, except pH and LOI.

SOIL AGGREGATES SIZE DISTRIBUTION

The soil aggregate mass distribution (kg/kg) was relatively uniform among sites with microaggregates (< 0.25 mm) ranging from 22 to 24% and the coarse aggregates (>1 mm) ranging from 58 to 64% (Fig.1a, 1b). Variation of the aggregate size distributions over time was largely insignificant and they appear related to the soil's natural heterogeneity. There were no significant differences attributed to the burning program or the liming treatment. The lack of soil structure degradation because of the burning program, as revealed by the maintenance of the aggregate mass distribution, reduces the likelihood for accelerated erosion because of the burning practices (Brady and Weil 1996).

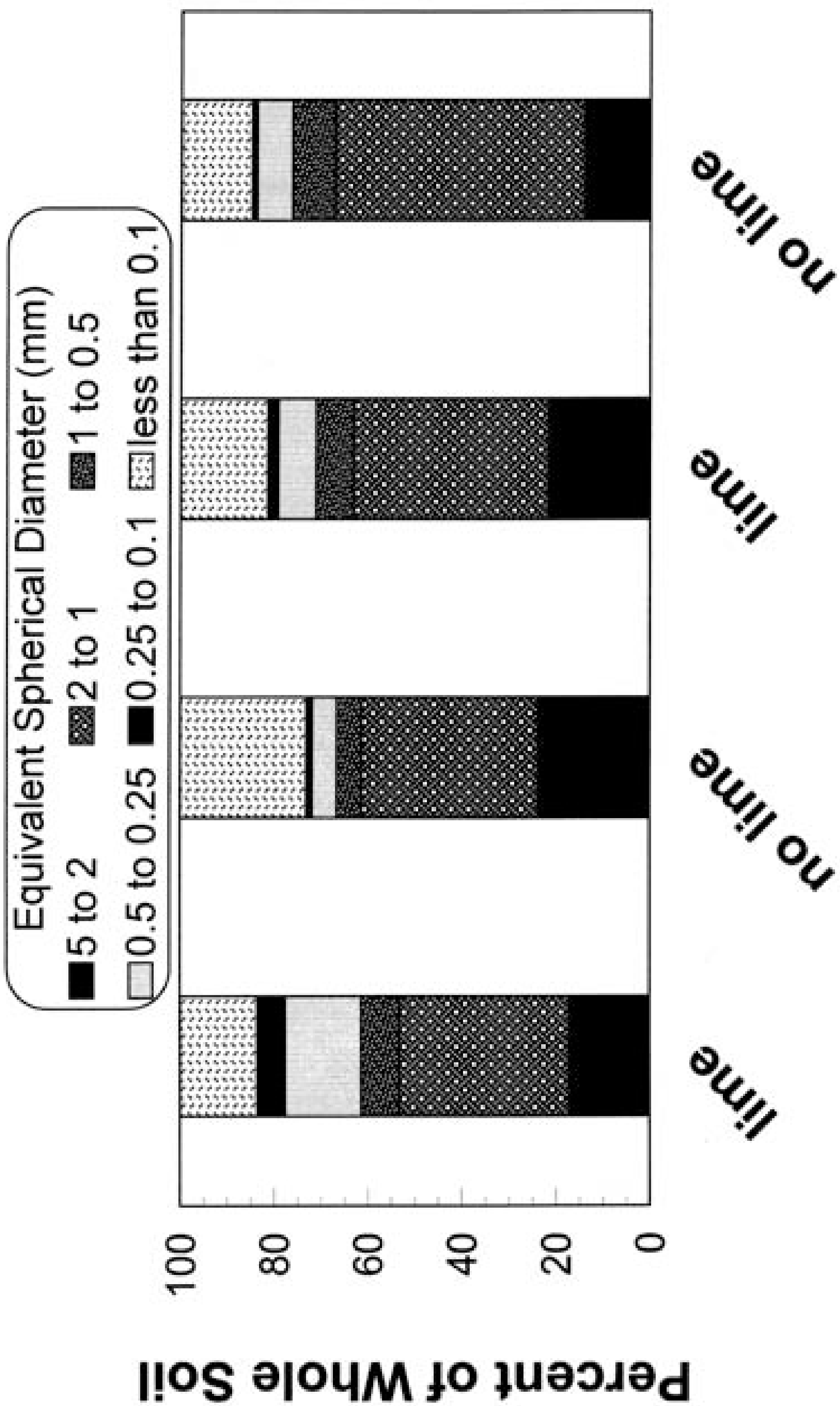

Fig 1a. Soil structure size distribution - Knobtop (Dec. 2000).

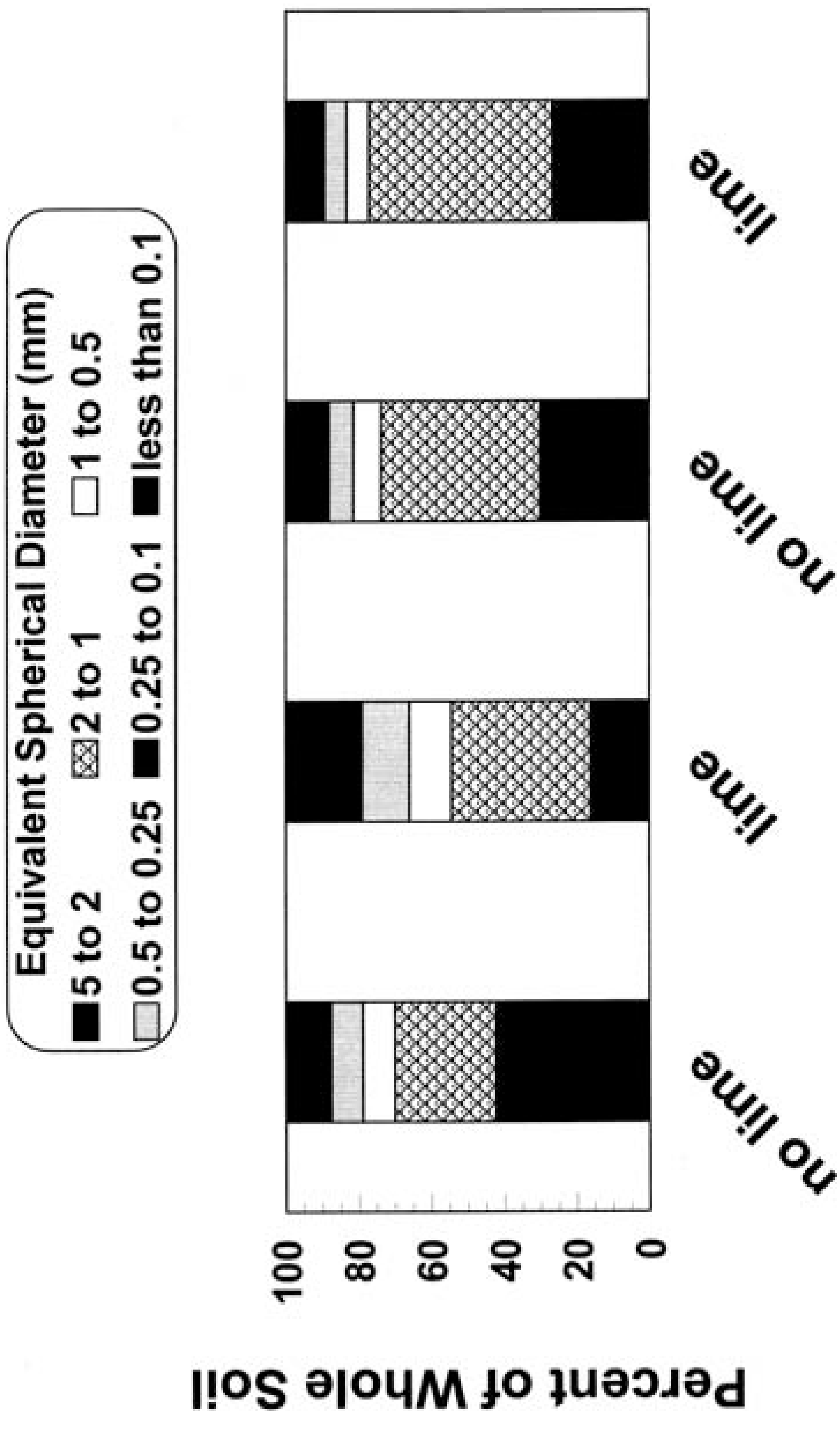

Fig. 1b. Soil structure size distribution - Taumsauk (Dec. 2000).

CHEMICAL PROPERTIES OF THE SOIL AND THE SOIL AGGREGATES

Each aggregate size was analyzed for pH, litter particles (POM), and humus (SOM). Coarse aggregates display a lower CEC, a feature likely attributed to smaller clay contents and higher quartz and feldspar contents. The CEC is greater in sites receiving lime (Fig. 2), an outcome of the pH dependent nature of SOM (Brady and Weil 1996). Chemical analysis of the aggregate classes show that the percentage ratios of calcium with the CEC (exchangeable Ca percentages or ECaP), are significantly different between the O and A horizons and because of the liming practices (Fig. 3). Calcium was indexed to the CEC to account for clay and SOM differences among the aggregate size classes. Liming treatments dramatically increased the ECaP. Fine aggregates from unlimed sites show a slight tendency to have smaller ECaP values, whereas in limed sites the fine and medium aggregates from the A horizons show greater ECaP. Apparently, the acid neutralization potential of the calcitic limestone is more effective towards the smaller aggregates. Interestingly, the O horizons generally have higher ECaP levels than the corresponding A horizons, possibly a combined consequence of their surface position and their initial contact with the lime and also because of calcium cycling by the vegetation. The total acidity, when indexed to the CEC, showed an expected inverse relationship with the ECaP concentrations (Fig.4), an outcome predicted by cation exchange reactions associated with liming practices (Brady and Weil 1996).

Unlimed aggregate pH values are extremely acidic and are roughly equivalent across the aggregate size classes; whereas limed aggregates are slightly acidic to acidic (Table 2). Smaller aggregates demonstrated less acidic pH values, corresponding to their greater ECaP concentrations. Thus, liming treatments did not uniformly alter the soil’s chemical properties, rather chemical changes were altered to a greater extent in the smaller aggregate classes. Particulate organic matter and loss on ignition values from the medium- and fine-sized aggregates are roughly equivalent and proportionally greater than for the coarse aggregates (Table 2).

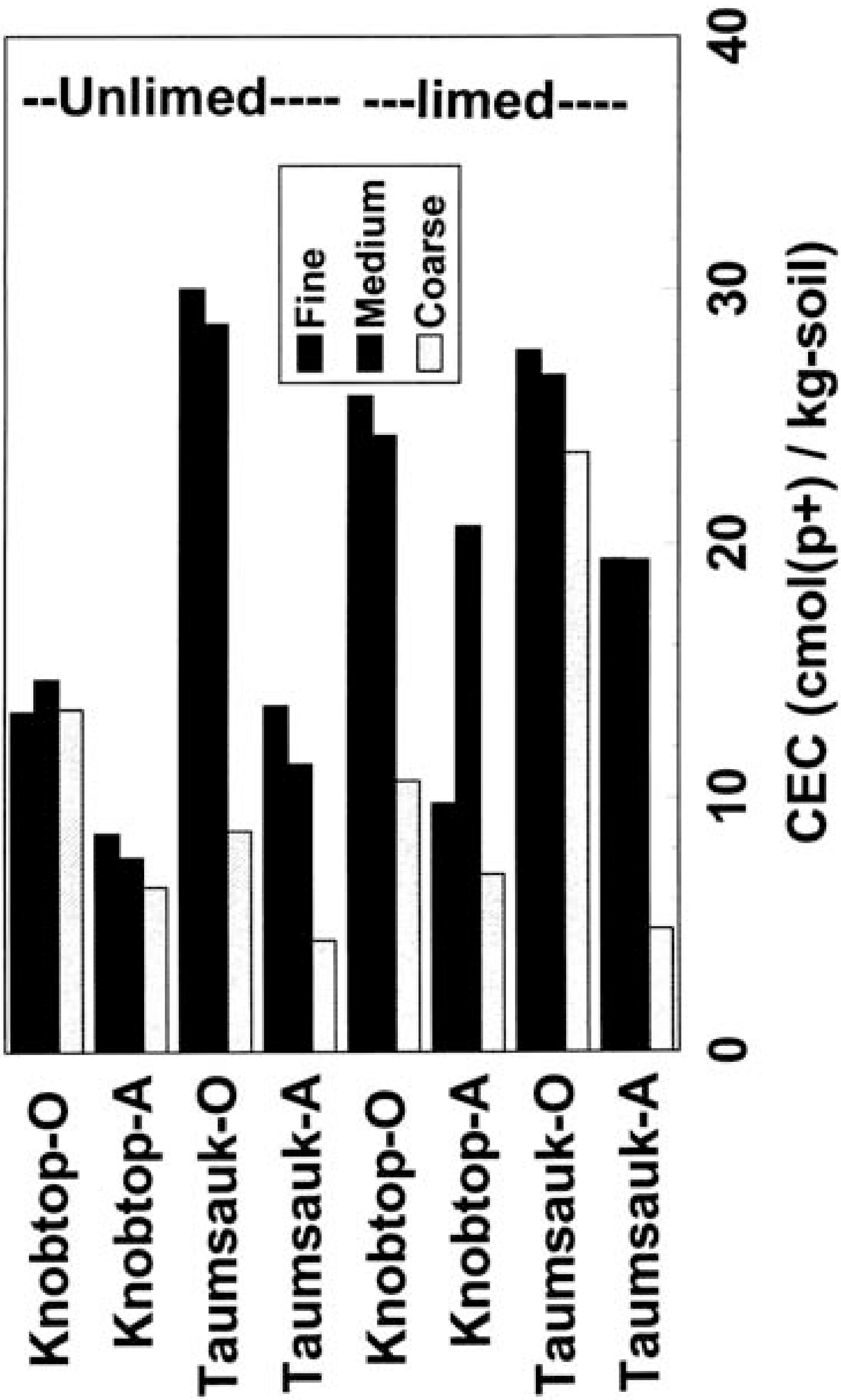

Fig. 2. Cation exchange capacity by aggregate class

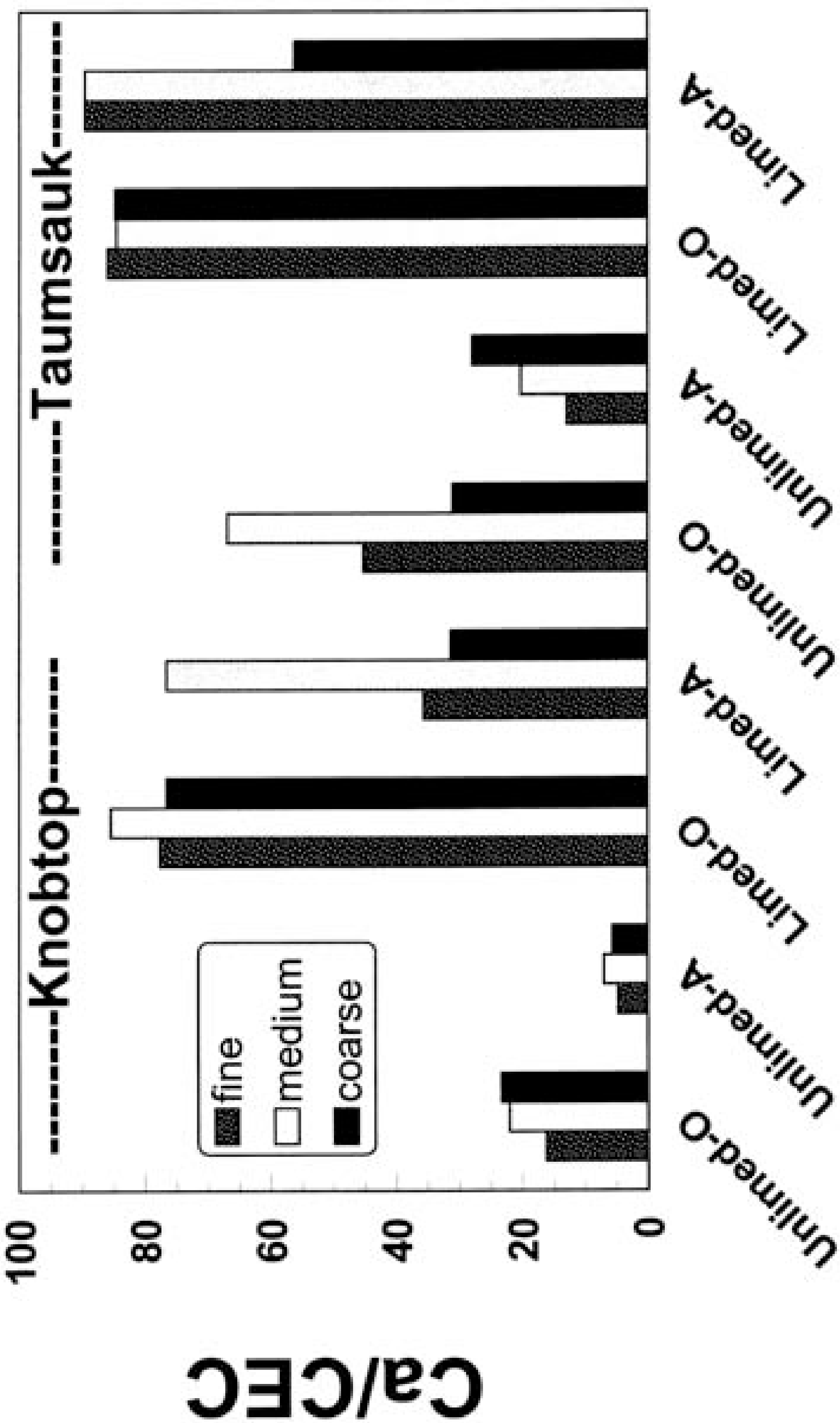

Fig. 3 . Exchangeable calcium percentage.

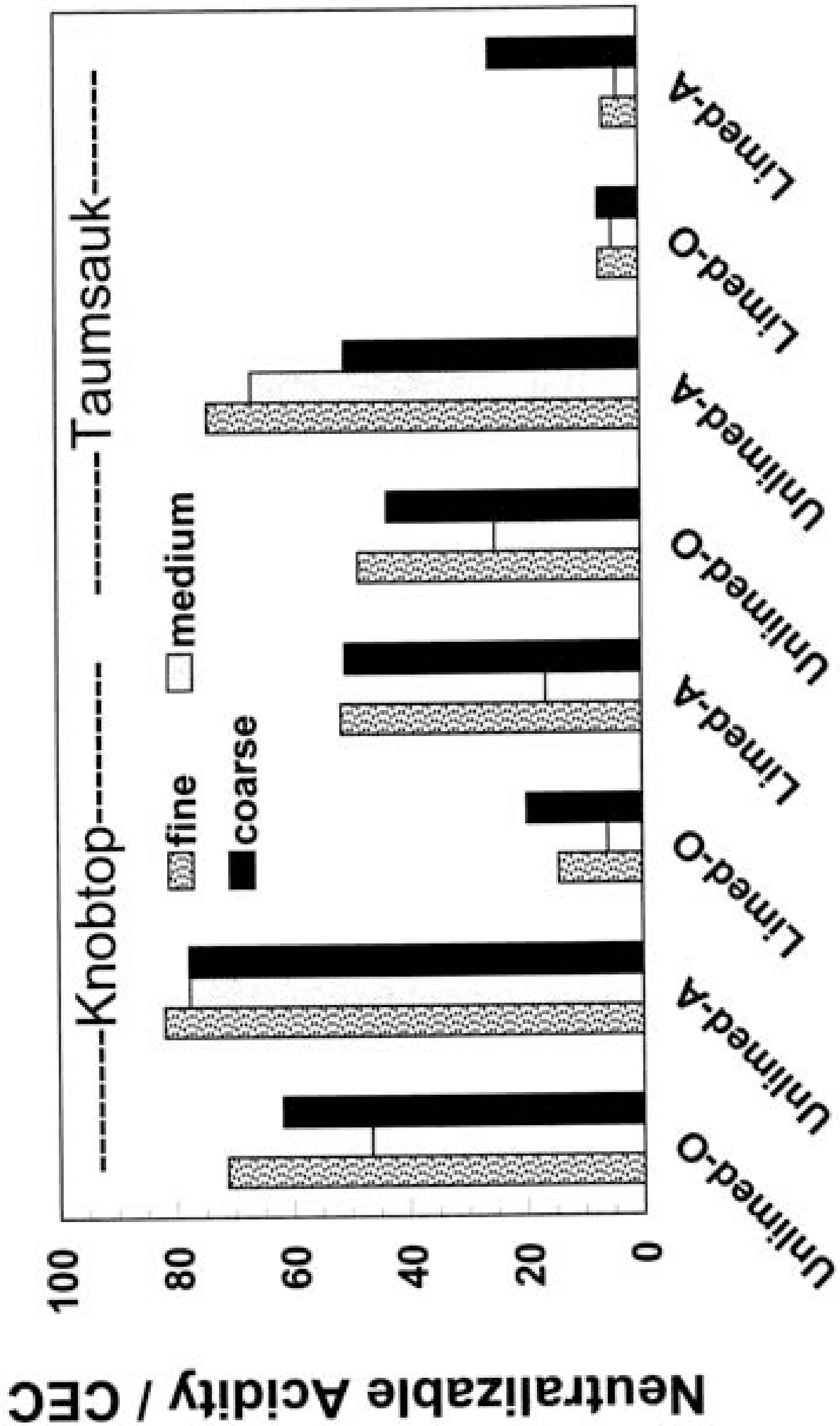

Fig. 4. Neutralizable Acidity as a function of liming

Table 2. Aggregate pH, loss on ignition (LOI), and particulate organic material (POM) sampled August 1999.

Treatment	Aggregate pH[¶] Coarse	Medium	Fine	LOI[§] Coarse	Medium	Fine	POM Coarse	Medium	Fine	pH[£]
	A- Horizon			Percent of Whole Soil						
Knobtop Sites										
Not Burned and Limed	4.7	4.8	5.6	5.9	8.7	8.9	2.3	2.9	1.7	5.8
Not Burned and No Lime	4.5	4.5	4.6	8.2	10.6	8.6	2.3	1.5	0.4	4.1
Burned and Limed	5.2	6.1	6.5	5.1	8.6	7.6	2.0	1.0	0.5	5.5
Burned and No Lime	4.4	4.3	4.5	8.9	8.7	8.9	2.0	2.6	0.9	4.7

¶ Coarse (>2 mm), Medium (2 mm to 0.25 mm), Fine (<0.25 mm)

§ LOI was determined after POM was determined.

£ pH is from O horizons.

Analysis of the Root Mat

The root-mat density varies from 0.17 to 1.2 kg-root • m^{-2} and the bulk density varies from 0.65 to 0.70 g-soil • cm^{-3} in the O horizons. The root mat density variation was spatially variable, reflecting the soil and forest variation. However, the presence of a living root-mat in the O horizon confers substantial protection to the soil, even after the removal of litter and vegetation because of fire. The abundance and resiliency of the root-mat guarantees the maintenance of the soil structure and fosters soil conservation (Brady and Weil 1996).

DISCUSSION

The controlled burning program was established to stimulate plant diversity; however, one question that needed to be addressed was the possible unintended consequence of accelerated erosion. As is commonly known, water erosion rates are affected by climate, soil properties, topography, vegetation, and human activities (Brady and Weil 1996). Soil properties key to influencing water erosion rates include texture, structure, SOM, drainage and permeability, and gravel content (Brady and Weil 1996). The controlled burning program did not influence the soil structure or the SOM content. In addition, the root-mat remained intact and living, providing a living web of strong tissue to anchor the O horizon and the underlying A horizon, providing protection against the rainfall's disruptive energy. Thus, a controlled burning program in the St. Francois Mountains should not accelerate soil erosion.

The liming program modified the soil's chemical properties, as expected and intended. However, the liming program did not equally modify soil associated with the variously sized aggregates, suggesting that soil horizons are not entirely homogeneous regions. The liming program did improve the soil fertility by increasing the CEC and the base saturation of the soil's exchange complex. These improvements should promote plant diversity by reducing the specter of aluminum toxicity and increasing the overall soil fertility.

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FEDERAL AND STATE PROGRAMS TO OFFSET COSTS OF SAVANNA RESTORATION

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ABSTRACT

Restoring savannas can be an expensive proposition. Costs associated with restoration activities such as tree clearing, replanting native grasses and forbs, prescribed burning, and controlling exotic plant species may be more than most private landowners or groups can bear on their own. There are a variety of programs, both state and federal, that can help offset some of these costs. This paper looks at some of the programs that can provide financial assistance to help ensure the success of savanna restorations.

INTRODUCTION

Every day we are gaining more and more knowledge of how to recognize, manage, and restore savannas, one of nature's most diverse communities. However, restoring savannas can be an expensive proposition. Costs associated with restoration activities, such as tree removal, planting native warm season grasses and forbs, prescribed burning, and controlling exotic species may be more than most private landowners or groups can bear on their own. There is a variety of state, federal, and private programs that can help offset some of these costs.

In my 25 years with the Missouri Department of Conservation, I have never seen so many programs, and so much financial assistance, available to the public. In this paper, I will try to give you a few ideas on where to look for financial assistance. Many of these are programs I deal with as regional supervisor for our Private Land Services Division. In our work with private landowners, we are always being asked if there is any financial help to install the practices we recommend.

We will look at some of the issues and situations that affect your search for financial help and then review some of the various programs that have the potential to help with your savanna projects.

A complete understanding of the programs in this paper is impossible. There are just too many programs with too many variables. I will just be providing some highlights. The details are found in the policies, guidelines, and specifications that go along with the individual programs. And, even though the rules are identical, what works for one person may not work for another. Or what works in one county may not work in another. The same could be said for different states. Programs are often influenced by local program staff or local work groups.

My goal is to make you more aware of the variety of available cost-share assistance. It is really up to each of you to search for the right program for you and your particular situation.

DISCUSSION

In Missouri, we know savannas can be found almost anywhere, and the same could probably be said for the rest of the Midwest and even the rest of the country. Do we even know what a savanna looks like? They are known by a variety of terms: oak barrens, oak openings, oak woodlands, oak savannas, savanna woodlands, and even wet, longleaf pine savannas. So, what IS the definition of a savanna? Regardless of your personal definition, the program you are working with may answer that question for you. Whether it is the soil type, amount of canopy coverage, or your management time frame, the program may define your parameters.

There are a few questions we have to ask ourselves. Is this a savanna restoration or reconstruction project? Is our project on private or public land? And finally, what can we expect in the way of future management on the site? If we don't consider these things initially, then we may be frustrated when we go out looking for financial assistance.

How long does the cost-share assistance program allow for completion of our project? Bringing back a savanna is never a short-term proposition, but restorations typically take a shorter length of time than a reconstruction. Reconstructions usually exhibit much less diversity than restorations, at least in the short term. Is this something we would be satisfied with?

When dealing with projects on private land, we have to make sure we are meeting the personal objectives of the landowner. Income from the land has to be considered. If our project can help provide income for the landowner, they will be much more willing to follow management guidelines, which helps ensure the success of the project. What kind of equipment and manpower will it take to complete our project? Public lands usually have much more of both available.

We all know that fire plays an important role in savanna management. Historically, we also know the dangers of fire. However, we have done such a good job of discouraging fire, we now need to convince people that burning of their savannas is necessary and we need to teach them to burn safely. We have already indicated that savanna restoration is a lengthy process. Who is going to do this work?

Savannas are some of the most diverse plant communities we have. Restoration of this diversity is our goal, regardless of what program we use to get there. You cannot just go shopping for a "Savanna Restoration Cost-Share Program." It does not exist. You have to break it down into management components. Think of tree removal, or grass and wildflower establishment, or burning when looking for financial assistance. Remember that different terminology can be used in different programs for the same practice. For instance, tree removal may be called woody vegetation control or timber stand improvement. They both accomplish the same thing. Of course, we always think of the more common practices, but you need to be more broad-minded. Things like prescribed grazing might be able to help you achieve your desired results.

We are now ready to look at some specific programs, but do not overlook technical assistance when working with private landowners. Many surveys show landowners place more importance in the technical assistance they receive than any financial assistance that might be available.

FINANCIAL ASSISTANCE PROGRAMS

Federal

On the federal level, the U.S. Department of Agriculture has four programs with the ability to restore savannas. These are the Wildlife Habitat Incentive Program (WHIP), the Environmental Quality Incentive Program (EQIP), the Conservation Reserve Program (CRP), and the Conservation Reserve Enhancement Program (CREP).

In Missouri, more than 4,800 acres of savanna habitat has been enrolled into the WHIP program, which is administered by the Natural Resources Conservation Services (NRCS). Approximately 15 to 20 percent of Missouri's funds ($350,000) has been directed toward savanna restoration, primarily through fire and tree removal practices. The future of the WHIP program is bright, including a possible increase in funding. WHIP works with a state's priorities. In Missouri, these are savannas, glades, and prairies. Because of the 5 to 10 year contracts available through WHIP, there is the potential for long-range management. This allows a participant to spread out the installation of their conservation practices over several years.

The EQIP program, administered by the Farm Service Agency (FSA), works through the State Technical Committee to set statewide resource concerns. In Missouri, Wildlife Habitat and Grazing Lands Health are the two statewide resource concerns that can best help in the restoration of savanna habitats. Nearly 53,000 acres in Missouri have been signed up in EQIP for upland habitat management systems. Of course, all of this is obviously not savanna, but this acreage amount points out the importance of this program. There are exciting prospects for EQIP in the new Farm Bill. A tremendous increase in funding has been discussed along with the ability to address additional resource concerns, going to a statewide program with no priority areas, and allowing shorter contracts. All these would make EQIP more attractive to its participants.

The Conservation Reserve Program (CRP) is another federal program administered by the Farm Service Agency. This program deals primarily with savanna reconstruction instead of restoration. In Missouri, the CP25 (Rare and Declining Habitat) practice has been used to address savannas, native prairies, and beginning in 2000, riparian forests. Nearly 26,000 acres have been signed up into the CP25 practice in Missouri between 1998 and 2001. The CRP program also provides long-term management through 10 to 15 year contracts. Financial assistance is available at a 50 percent cost-share rate for installation of the practices. Annual rental payments are also available.

Although similar to CRP in application, the Conservation Reserve Enhancement Program (CREP) may actually work a little better for true savanna restorations. In Missouri, we have seen limited enrollment in CREP, but it has been used extensively around drinking water supplies. However, in Illinois, CREP has been used along the Illinois River to help restore oak savanna ecosystems.

The Partners for Fish and Wildlife Program, through the U.S. Fish and Wildlife Service, is probably its best program for providing savanna restoration management. It has been very popular in Missouri, although I don't think we have reached our potential for savanna restoration. We have enrolled 200 landowners and more than 3,000 acres of upland habitat into the program.

State

State programs around the country are numerous and varied. While maybe more subject to funding instability than federal programs, state agency programs are a good place to look for financial help, not to mention the technical assistance they can provide.

In Missouri, the Department of Conservation invests about $1 million per year into our Landowner Assistance Program. Practices such as native grass establishment, prescribed burning, invasive species control, tree removal, and livestock exclusion are cost-shared at rates of 50 to 75 percent.

Two new programs in Missouri are the Missouri Ecotype and Grow Native programs. Both of these programs promote a greater use of native plants, both on a backyard and a landscape scale. It is hoped that one spin-off of these programs will be to encourage more savanna and prairie restoration projects.

The Missouri Department of Natural Resources' Soil and Water Conservation Program addresses thousands of acres per year. While the program's goals are tied heavily to erosion, there are ways it can help with savanna restoration, such as a livestock fencing practice for slopes greater than 10 percent. The Equipment Loan Program is very popular and allows local Soil and Water Conservation Districts to lend or rent equipment to landowners. This equipment can range from prescribed burning equipment to native warm season grass drills.

The Department of Natural Resources in Minnesota has the Conservation Partners Grant Program that can provide funding to improve native plant habitats. Grants in the amount of up to $20,000 are available to private groups, cities, counties, townships, and school districts. The grants must be matched at a 50 percent rate through non-state contributions of cash, materials, or in-kind services.

The Quail Habitat Initiative is a joint venture between the Missouri Department of Conservation and Quail Unlimited. Funds raised by local Quail Unlimited Chapters are matched by the department. Since 2000, nearly $205,000 has been allocated to encourage development of quail habitat through Quail Unlimited's CORE 4 Practices. This program includes practices that can easily be used to restore savannas, as long as they also improve quail habitat.

In Missouri there is a source of information that provides more detailed information about the various federal and state programs available to its citizens. The best place to access this information is through the Web site of the Missouri Watershed Information Network, or MoWIN. The Web site can be found at http://outreach.missouri.edu/mowin.

Private

Environmental grants are an excellent place to look for financial help to restore savannas. You'll find grants offered through various state and federal agencies, environmental groups and private industry.

An excellent example of this is the United Sportsmen's League out of St. Louis, Missouri. This group offers four, $500 grants to Missouri Chapters of Future Farmer of America (FFA). A Glade/Savanna Management project is even given as one example in their grant application literature. Practices can include re-establishment of native plants, fencing to regulate grazing, and prescribed burning.

The National Fish and Wildlife Foundation (NFWF) provides a variety of private land grants, typically in the $25,000 to $75,000 range. Missouri is currently working with two NFWF grants totaling $250,000 for prairie work that easily could have been for savannas, if the grants had been written differently. The practices include prescribed burning and woody vegetation control.

The National Wild Turkey Federation has also been active in Missouri. Through its Superfund Grant, the federation has provided several thousand dollars for habitat practices and equipment. Much of this work has been done on savanna habitats. These funds have been used to match funding in the Conservation Department's Landowner Incentive Program. They have also purchased equipment such as prescribed burning equipment, ATV native grass seeders, and rotary cutters for use on both private and public land.

Partnering opportunities should never be overlooked. These types of cooperative efforts can mean the difference in being awarded a grant from private foundations. An excellent example is the grant awarded through the Indiana Power and Light Company's Golden Eagle Environmental Grant Program. A $10,000 grant for savanna restoration was given to the city of Portage, Indiana, and its partners. Part of this project included habitat restoration for a listed butterfly species, illustrating the importance of partnering in getting private foundation grants.

In addition to restoration and reconstruction projects, do not overlook programs that help preserve and protect savannas. An example of this would be the Minnesota Department of Natural Resources' Natural and Scenic Area Grant Program. This program can provide a maximum grant of $500,000, with a 50 percent match, for fee title acquisition and permanent easements.

There are hundreds of foundations that can be a source of funding. A good place to look for information is the Web site of The Foundation Center (www.fdncenter.org). Also, check out local grant writing workshops. These workshops cannot only provide suggestions on where to look for natural resource grants, but they can teach you the proper way to write grants.

SUMMARY

This paper has introduced some of the various federal, state, and private financial assistance programs available to help restore savannas. There is no way to know and understand all the available programs. Programs are constantly changing because of budgets, priorities, changes in funding sources, etc. And finally, look beyond financial help. Sometimes we get too dependent on cost-share programs. Look for ways to minimize costs in your savanna work. Work with local FFA Chapters or Boy Scout troops on that project to clear unwanted trees off that savanna. Set up a landowner coop or get the local Quail Unlimited Chapter involved in helping you burn that savanna. Restoration of savannas is our goal, regardless of how we get there.

FIRE RESTORATION OF A FRAGMENTED POPULATION OF COLLARED LIZARDS (*CROTAPHYTUS COLLARIS*) ON THE OZARK PLATEAU - EVIDENCE FROM GENETIC AND LIFE-HISTORY DATA

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INTRODUCTION

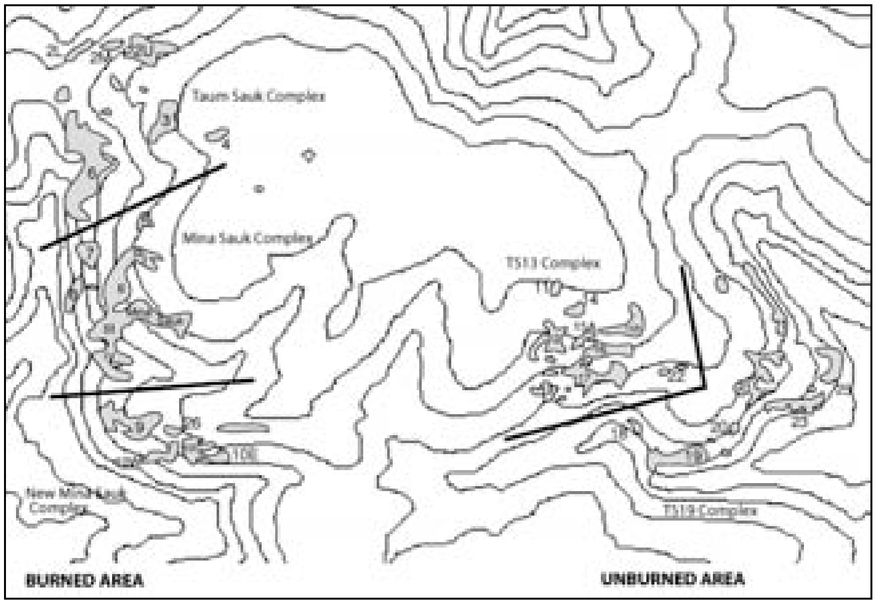
Habitat fragmentation due to human activity is an increasingly recognized phenomenon with potentially severe consequences for the survival of fragmented populations (e.g. Brown 2001, Gigord et al. 1999). Fragmented populations often experience a decrease in size and a loss of genetic diversity that in turn can result in decreased population viability, increased sensitivity to stochastic environmental changes, and increased likelihood of local population extinction. The absence of individual movement between populations (another consequence of habitat fragmentation) can lead to an "extinction ratchet," in which open habitat is not recolonized following local extinction, eventually resulting in global extinction (Templeton et al. 1990).

Eastern collared lizards (*Crotaphytus collaris collaris*) in Missouri have been undergoing dramatic habitat fragmentation over the past 100 years due to human activity; specifically the suppression of fire on and around the glade habitat that supports them. Fire suppression has created a dense understory in the forest surrounding these glades, rather than the open savannah that existed prior to fire suppression (Beilmann and Brenner 1951), and collared lizards do not readily disperse through this dense forest (Templeton et al. 2001). In addition, fire suppression has led to a loss and degradation of glade habitat due to invasion by fire-sensitive eastern redcedar and successional invasion by other woody species, further threatening the long-term survival of collared lizards in Missouri (Templeton et al. 2001). A burn management program can potentially counteract these effects by expanding and improving glade habitat and opening the forest that surrounds the glades.

METHODS

We have been monitoring a population of collared lizards at Taum Sauk Mountain State Park and adjoining Missouri Department of Conservation and private lands in Iron County in southeast Missouri as part of a mark/recapture and genetic study to examine the effect of fire on the population structure and health of this species. Our study site includes a cluster of glades within a burn management area overseen by the Missouri Department of Natural Resources and a cluster outside the burn area. Burns were first conducted in this area in late 1992, and again in 1994, 1998, and 2001. In the approximately 10 years prior to burning, there was no evidence of glade-to-glade dispersal during sporadic surveys, including between glades separated by less than 100m.

For our analyses, we have broken the glades in the burned area into three complexes – the Taum Sauk Complex to the north, the Mina Sauk Complex in the middle, and the New Mina Sauk Complex to the south (see glade map). These are natural units in that distances between glades within complexes are relatively small, while distances between glades in different complexes tend to be larger. We have divided the glades in the unburned area into 2 complexes – the TS13 Complex and the TS19 Complex. These are also natural units and are comparable in size to the burned area complexes.



We monitored the glades in the burned area for 4 seasons starting in 1998 and the glades in the unburned area for 2 seasons starting in 2000. Lizards were caught by noosing or by hand and were individually marked by toe clipping. Several body measurements including weight, snout-vent-length, and tail length were taken, and either blood or toes were collected for genetic analysis. Lizards were then released at the site of capture. Mark/recapture data were used to examine dispersal frequency and distance and to estimate population sizes. Body size measurements were used to calculate growth rates and age- and sex-specific average sizes.

Genetic variation was assessed using microsatellite genetic markers, short sequences of DNA ("CAG" for example) that are tandemly repeated anywhere from several to over 100 times (Goldstein and Schlotterer 1999). Different copies, or alleles, of these microsatellites vary in the number of repeat units they possess, and the geographic distribution of these alleles was used to assess population genetic structure (Avise 1994).

Under a more connected population structure (such as we would expect to see under a burning regime), dispersals between different glades should result in those glades becoming genetically more similar to each other. Alternatively, under a more fragmented population structure, one would expect different glades to be more genetically differentiated as the isolated populations evolve independently. We are testing these predictions with our microsatellite data using the population genetic parameter Fst, which measures the amount of genetic variation between populations relative to the amount within populations (Wright 1951). Fst values can range from 0 to 1, with higher Fst's reflecting more population differentiation - an Fst of 0 means that all variation occurs within populations (i.e. different populations are genetically identical to each other), whereas an Fst of 1 means that there is no variation within populations and no similarity between populations. We predict that Fst's between burned glades should be lower than Fst's between unburned glades and that Fst's between burned glades should decline with time due to increased dispersal in the burned area.

RESULTS

Dispersals

In 4 years of sampling in the burned area, we caught 129 unique individuals; 51 individuals were caught in 2 years of sampling in the unburned area. Approximately two-thirds of the lizards were captured more than once (average 4.3 captures). Most lizards that were not recaptured were hatchlings caught late in the season, and these lizards have relatively high mortality over their first winter (Fitch 1956).

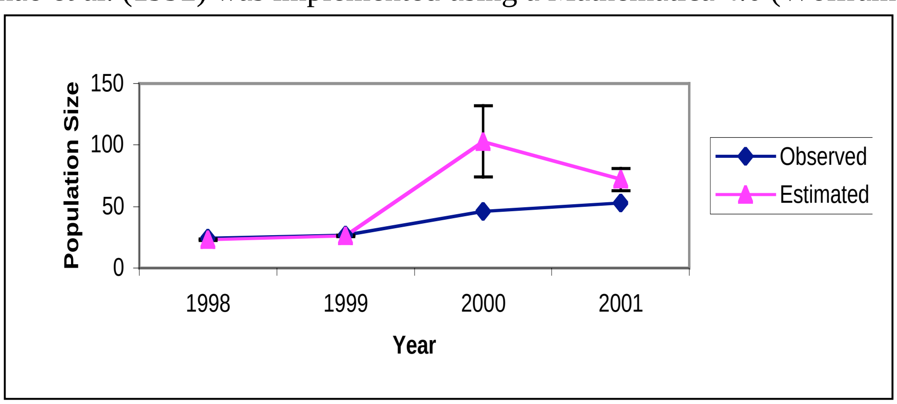
Dispersals occurred more frequently in the burned area relative to the unburned area (see table; dispersal frequencies were evaluated by comparing the number of animals recorded dispersing to the number of animals recaptured, since an animal must be caught at least twice to be observed moving between glades), although this difference was not statistically significant at the 0.05 level. Dispersals were significantly longer in the burned area than the unburned area, comparing both burned data for all four years (one-sided t-test, $P = 0.039$) and for 2000-2001 only ($P = 0.033$) to unburned data for 2000-2001 (see table). In addition, we recorded seven dispersals between complexes in the burned area and no dispersals between complexes in the unburned area.

	Number of animals recaptured	Number of animals dispersing	Dispersers/ recaptures	Dispersals between complexes	Average dispersal distance (m)
Burned, all years	85	29	0.34	7	320
Burned, 2000-2001	50	17	0.34	3	380
Unburned, 2000-2001	31	7	0.23	0	210

Population Growth

We used mark/recapture data to estimate population sizes in the burned area. Sampling was not intensive enough in 2000 to allow meaningful between-year comparisons in the unburned area, so only population data from the burned area are presented here. A non-parametric estimation technique developed by Chao et al. (1992) was implemented using a Mathematica 4.0 (Wolfram 1999) program written by A. R. Templeton.

There is a significant increase in population size over the 4 years of sampling in the burned area (see graph). This increase is significant based both



on the actual numbers of lizards caught (one-sided t-test, $P = 0.004$) and on the estimated population sizes ($P = 0.029$). The estimate for 2000 is higher and has a much wider variance because sampling in the burned area was not as intensive that summer, and our estimation technique inferred a lower sample coverage than in other years. The overall trend for all 4 years is nevertheless a significant increase in population size.

Part of this increase in population size, at least in the last 2 years, is due to the colonization of previously unoccupied glades, including an entirely new complex (the New Mina Sauk Complex at the south end of the burned area; see glade map above). We monitored this complex in 1998 and 1999 without seeing any evidence of collared lizards; but in 2000, we began to catch lizards there. The first lizards caught were ones that we had initially captured on the Mina Sauk Complex. However, in 2001 we caught a total of 16 lizards on the new complex, including both new ones and ones previously captured on the old complex.

One of the glades in the New Mina Sauk Complex (glade 26; see glade map above) would almost surely be too small to support a collared lizard population in isolation; however, we have caught lizards on this glade and on other comparably sized glades in the burned area. This illustrates another advantage of dispersal between glade populations – glades that are too small to support viable populations in isolation can still be useful as temporary habitat and can contribute to the overall capacity of the complex to support collared lizards. We have not found evidence of collared lizards on comparably sized glades in the unburned area.

Genetic Differentiation

Preliminary genetic analysis also reveals a pattern of reconnection of glades in the burned area, while glades in the unburned area are highly differentiated. Two glades were arbitrarily chosen from the burned area, and 2 glades of comparable population size and a comparable distance apart were chosen from the unburned area. For each of these glade pairs, pairwise Fst's were calculated. Fst's were calculated for all 4 years on the burned side; on the unburned side, population sizes were large enough for a meaningful Fst calculation in 2001 only. Fst's in the burned area have decreased for all 4 years of the study, and they are substantially lower than the Fst in the unburned area for 2001 (see table). (As discussed above, Fst values can theoretically range from 0 to 1. However, a common method used to calculate Fst (Weir and Cockerham 1984) makes adjustments for small and uneven sample sizes, and this allows for slightly negative Fst values, as seen for the burned glades in 2001. This value can be interpreted as being no different from an Fst of 0.)

Glades	Fst
Burned 1998	0.1242
Burned 1999	0.0926
Burned 2000	0.0315
Burned 2001	-0.0751
Unburned 2001	0.2918

It must be noted that these Fst values do not imply that there is less genetic diversity in the burned area than in the unburned area; in fact, there are actually slightly more alleles in the burned area for the microsatellites presented here. Rather, these Fst's are a measure of *differentiation between glade populations* within the burned and unburned areas, and they reflect the amount of dispersal and gene flow occurring in these areas. These data suggest that glades in the burned area are becoming genetically more similar to each other as lizards are able to more freely disperse between them, while the more limited dispersal in the unburned area is reflected in the substantially higher Fst value for this area. Finally, it should be noted that these are very preliminary genetic results. Patterns of genetic differentiation in the burned and unburned areas will become more resolved as more microsatellites are included and additional glade comparisons are made.

Growth/Body Size

We used our snout-vent-length measurements to calculate body sizes and growth rates for our lizards in the burned area and compared these values to previously reported values for a population of collared lizards in eastern Missouri, approximately 100km northeast of Taum Sauk Mountain. Sexton et al. (1992) reported results of a long-term study in which they monitored a population of collared lizards on a glade at this site in the 1960's, when the glade habitat was in relatively good condition, and again in the 1980's, when the habitat had deteriorated due to invasion by woody vegetation. They found that collared lizards on degraded glade habitat were smaller and grew at a slower rate than those on healthy habitat; they attributed this reduction in body size and growth rates to reductions in the availability of food and high-temperature perching areas due to glade degradation. We found that our burned area lizards were not significantly different from Sexton et al.'s healthy glade lizards in body size and growth properties, and for most age and sex comparisons our burned area lizards were significantly larger and faster growing than Sexton et al.'s degraded glade lizards (Brisson et al. in submission).

It will be interesting to compare our lizards in the burned and unburned areas, and to compare our unburned area lizards to Sexton et al.'s 2 populations. Unfortunately, since we have only been monitoring the unburned area for 2 seasons, and since we can only reliably age hatchlings and yearlings, we do not have large enough samples sizes to make meaningful comparisons involving our unburned area lizards. After 1-2 more field seasons, we will be better prepared to make these comparisons.

SUMMARY/CONCLUSIONS

Several lines of evidence suggest that the burn management program at Taum Sauk Mountain has resulted in the reconnection of previously isolated glade populations of collared lizards. Dispersals are higher in both frequency and distance (although the frequency change is not significant at the 0.05 level) in the burned area relative to the unburned area. In addition, population sizes have steadily increased in the burned area during the 4 years of our study. This population increase is partially the result of the colonization of previously unoccupied glade habitat. Preliminary genetic data also suggests a pattern of reconnection of glades in the burned area, while glades in the unburned area are still highly differentiated. Finally, we have presented growth and body size data suggesting that our populations in the burned area are similar to a previously described healthy population of collared lizards in Missouri; these populations have larger body sizes and growth rates than a population living on deteriorated glade habitat (Sexton et al. 1992).

This should be good news for the long-term viability of these populations for several reasons. First, increased population size will act as a buffer against local population extinction due to any stochastic environmental events, and it will also limit the loss of genetic diversity due to genetic drift (Hartl and Clark 1997). In addition, the ability to recolonize glades whose populations may go extinct will act as a buffer against global population extinction in this area, and the ability to make use of glade habitat that would be too small to support an isolated population will increase the population capacity of this area.

Similar results have been obtained from a related study described in Templeton et al. (2001). Templeton et al. examined collared lizard populations that had been translocated into the Stegall Mountain Natural Area in southern Missouri in the mid-1980's. No dispersals were recorded in these populations prior to the initiation of a fire management program in 1994. Under the fire management program, dispersal between glades and colonization of unoccupied glade habitat began to occur at a high rate. However, there are several important differences between these 2 studies. First, Taum Sauk collared lizard populations are natural remnant populations, rather than translocated populations, as at Stegall Mountain. Thus, the Taum Sauk populations illustrate a common natural condition for species of conservation concern - remnant or fragmented populations on degraded habitat. Second, the Stegall Mountain study is primarily a temporal contrast between pre- and post-burn populations. While the Taum Sauk study has a temporal component as well, there is also a spatial contrast between nearby glades within and outside of the burned area. Finally, the Stegall Mountain study did not address the effects of prescribed burning on individual body sizes and growth rates, or on population genetic structure. Both of these questions are and will continue to be addressed in this study.

The data presented here and in Templeton et al. (2001) suggest that collared lizard populations in the Ozarks can benefit from prescribed burning. Collared lizards are one of a variety of desert-adapted plants and animals that are restricted to glade habitat in the Ozarks, and these other organisms are also threatened by the glade fragmentation and deterioration that has resulted from fire suppression. An earlier study of lichen grasshoppers (*Trimerotropis saxatilis*) showed that these populations have also undergone recent population fragmentation, presumably as a result of fire suppression (Gerber and Templeton 1996). We are currently working on a genetic survey of lichen grasshopper populations in burned and unburned areas, and colleagues at Washington University are initiating pilot genetic studies of two glade-restricted plant species. These studies will be important in determining the broader role of fire management in restoring the health and connectedness of the glade-endemic flora and fauna of the Ozark Mountain region.

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THE HERPETOFAUNA OF A FIRE MANAGED OZARK WOODLAND IN SHANNON AND CARTER COUNTIES, MISSOURI: PRELIMINARY RESULTS

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ABSTRACT

Prescribed fire management is increasingly being used in land management for its beneficial effects on the landscape and the biota. Faunal responses to fire are not well known, but are important to the overall health of the landscape. A long-term herpetofaunal monitoring study at Chilton Creek in the lower Ozarks of Missouri was initiated in 1997. Time-constrained searches (TCS) were used to inventory and monitor reptiles and amphibians in this 5,600-acre woodland preserve. Fire management began in treatment units in 1998 and continued in 1999. Preliminary results indicate that initial fire treatments had no significant negative effects on the herpetofauna at the community level. This study also illustrates that the scale of sampling is critical given the amount of spatial heterogeneity in such a woodland, which can obscure subtle treatment effects.

INTRODUCTION

Prescribed fire management is increasingly being used in land management for its beneficial effects on the landscape and the biota. There is evidence that frequent fire was ubiquitous in many regions of North America, prior to European settlement (Ladd 1991) which left behind a legacy of open grasslands and savanna woodlands adapted to fire. Studies have shown that the introduction of fire management increases plant species diversity (TNC unpublished data), but the effects on many of the animals, including the herpetofauna are not well known. Responses of amphibians and reptiles may be short term, affecting individual animals; or long term, affecting populations and their persistence within the community. Documented responses include fire avoidance behavior among snakes (Rudolph et al. 1998), and incidental fire-related mortality (Erwin and Stasiak 1979). Corn and Peterson (1996) argue that the benefits of long term habitat changes resulting from fire outweigh the cost of any damage done to individual animals. Beyond that the literature is depauperate of long term population trends for reptiles and amphibians in North America due to fire, though understanding these trends is critical for appropriately managing fire-dependent systems.

STUDY SITE

Chilton Creek Preserve, located in the lower Ozarks of Missouri, is a 5,627-acre woodland, surrounded by nearly continuous woodland habitat. It consists of well-drained cherty soils on steep slopes, with numerous dolomite and sandstone outcrops, and occasional fens, glades, and intermittent streams, which eventually drain into the Current River, on the east side of the preserve.

METHODS

Six site visits were made in 1998 and 1999, collectively, following baseline data collection in 1997 (included in inventory results) and the initiation of fire management. Fourteen sample sites were randomly located in the areas targeted for burning. Both north- and east- and south- and west-facing slopes were well represented. Another 11 points were randomly selected outside the areas targeted for burning. Plots were sampled with time constrained searches 3 times per year in spring and fall when amphibians and reptiles were most likely to be surface active. Volunteers assisted with sampling on 3-4 day trips, varying in length depending on the number of volunteers. On each visit, 1 to 4 workers spent a total of 1 person-hour at each plot. Logs, rocks and other debris were systematically rolled or lifted and then replaced, recording each animal that was encountered. All 25 plots were searched in a different sequence during each visit to minimize time and weather related bias. A site herpetofaunal inventory list was created with TCS and additional searches of habitats not well represented in the sampling plots. The slope-aspect of each plot was also noted.

RESULTS

Inventory

To date, 43 species have been found (Appendix 1) at the site; 29 of them on plots during TCS and 14 using other search techniques. A total of 1,270 individual animals were recorded during TCS and 359 individuals were noted during other searches on the preserve, for a total of 1,629 animals found at the site. During all seasons and including all search methods, the most common species was the western slimy salamander *(Plethodon albagula)*, followed by the dark-sided salamander *(Eurycea longicauda melanopleura)*. Together these 2 salamander species made up 81% of the total sample. No other species exceeded 9% and most species each made up 1% or less of the total.

Fire Effects

The effect of fire was analyzed in 3 ways on TCS data: principal components analysis (PCA) on community structure, Wilcoxon signed ranks test by groups (Caudata, Anura, Lacertilia, Testudinata and Serpentes), and Wilcoxon signed ranks test by species on species exceeding 20 observations (8 species). Principal components analysis revealed no strong pattern in community structure due to fire. The Wilcoxon signed ranks test by groups found 3 groups with significant fire effects: Caudata, Lacertilia and Testudinata and the Wilcoxon signed ranks tests by species found no significant fire effects.

Slope-Aspect

Slope and aspect were also tested as a possible factor in community structure with PCA and with Wilcoxon signed ranks tests on community structure, groups and species with more than 20 observations. Slope was not significant in any of these tests.

DISCUSSION

While TCS have not traditionally been used in Midwestern herpetofaunal studies, they are a cost effective method with reasonable labor requirements. TCS are appropriate when the objective is to determine population trends, when sampling will be conducted over a long period of time, and when habitat structure (presence of cover objects or other habitat features which make detection of animals feasible) is appropriate. Likewise, the issue of scale is critical in sampling a heterogeneous environment. We believe that there are 2 possible explanations for failing to detect significant fire effects at the community and species level, if they exist. Either there is a lag time associated with herpetofaunal response following fire, or the response was too subtle for the scale at which we sampled. Factors such as weather, time of day, heterogeneity of biotic and abiotic conditions among plots, and variation in fire intensity among plots may have obscured some of the fire effects. Over the short-term, the scale at which we sampled may be inappropriate to detect these changes; however, we believe that our scale of sampling is appropriate for detecting long-term trends. It is interesting that a significant fire effect was detected at the Order level for 3 groups, but that slope-aspect had no effect. Since slope-aspect can drastically influence local conditions and fire behavior, one might expect reptiles and amphibians to respond differentially to north-facing and south-facing slopes

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

We conclude that fire was not detrimental to the herpetofauna at Chilton Creek over the short term (2 years). Species and communities remained statistically unchanged, though salamanders, lizards and turtles, each as a group, appear to have increased after fire. It remains uncertain what the long term effects will be after additional years of burning and sampling. It is anticipated that changes in herpetofaunal populations will be associated with vegetation structural changes over many years which will change the amount of moisture and sunlight in each microhabitat as well as many other factors. Historically, when these woodlands were more open, amphibians likely occurred proximate to stream corridors, or may have been associated with a dense herbaceous layer. Long-term effects of fire on herpetofaunal populations can only be determined through more fire treatments and monitoring. The 2-year post-fire results of this study lend support to the benefits of fire management.

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APPENDIX 1

Species found at Chilton Creek Preserve

Species	Common Name
Ambystoma maculatum	spotted salamander
Eurycea longicauda	long-tailed salamander
Eurycea lucifuga	cave salamander
Hemidactylium scutatum	four-toed salamander
Notophthalmus viridescens louisianensis	central newt
Plethodon albagula	western slimy salamander
Plethodon serratus	southern red-backed salamander
Typhlotriton spealaeus	grotto salamander
Acris crepitans blanchardi	Blanchard's cricket frog
Bufo americanus charlesmithi	dwarf American toad
Bufo fowleri	Fowler's toad
Hylo chrysoscelis/versicolor	gray treefrog
Pseudacris crucifer crucifer	northern spring peeper
Rana catesbeiana	bullfrog
Rana clamitans	green frog
Rana palustris	pickerel frog
Rana sphenocephala	southern leopard frog

APPENDIX 1 (CONTINUED)

Species	Common Name
Apalone spinifera spinifera	eastern spiny softshell turtle
Graptemys geographica	common map turtle
Chelydra serpentina serpentina	common snapping turtle
Terrapene carolina triunguis	three-toed box turtle
Cnemidophorus sexlineatus sexlineatus	six-lined racerunner
Eumeces anthracinus pluvialis	southern coal skink
Eumeces fasciatus	five-lined skink
Eumeces laticeps	broad-headed skink
Sceloperus undulatus hyacinthinus	northern fence lizard
Scincella lateralis	ground skink
Agkistrodon contortrix	copperhead
Agkistrodon piscivorus leucostoma	western cottonmouth
Carphophis vermis	western worm snake
Crotalus horridus	timber rattlesnake
Diadophis punctatus arnyi	prairie ring-necked snake
Elaphe obsoleta obsoleta	black rat snake
Heterodon platyrhinos	Eastern hog-nosed snake
Lampropeltis triangulum syspila	red milk snake
Nerodia sipedon sipedon	northern water snake
Opheodrys aestivus aestivus	rough green snake
Sistrurus miliarius streckeri	western pygmy rattlesnake
Storeria dekayi wrightorum	midland brown snake
Storeria occipitomaculata occipitomaculata	northern red-bellied snake
Thamnophis sirtalis sirtalis	eastern garter snake
Virginia striatula	rough earth snake
Virginia valeriae elegans	western earth snake

FIRE MANAGEMENT FOR WILDLIFE, CATTLE, AND NATURAL COMMUNITIES

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Introduction by Ken McCarty:

Years ago, when we were burning units of 20, 50, and even 100 acres, we went to visit Paul Martin. He showed us 2,000 to 3,000 acre units that he was burning. He was treating whole landscapes. He was doing ecosystem management years before people even started talking about ecosystem management. It was purely inspirational for me. So, today I am very pleased that we were able to get Paul to come out of retirement, and speak to us about his savanna management accomplishments, especially some of the highlights of his grazing program.

Paul Martin:

I have been impressed with this entire session. The previous speakers have had a lot of research behind what they presented. Their slide presentations, well actually they were not even slide presentations anymore, they were computer generated programs, and well, their programs were outstanding.

Now, I am going to take you back in time, back to a time when speakers used slide projectors. I think this is why they put me toward the end of the program. They wanted you to see how far they have come in the last 10 years, since I retired. In my area, the south-central part of Missouri, we have a million and half acres of glades and savannas. There are extensive glades and in between the glades are acres and acres of savanna. This is where I did the management that I'm going to discuss.

In this region of the state, the livestock owners were so far apart that they couldn't have regular church services so they had what they called First Sunday. As you can guess, the First Sunday was the first Sunday of every month. They would meet on a glade or a "bald" as they called them and they would have a 3-day service. I feel kind of like the preacher who was in the last day of the 3-day service, everybody is ready to go home.

Kuchler developed a natural vegetation map of Missouri. He called my region the cedar glade region. Steyermark referred to the region as the cedar bluestem region. Each of them put cedar in the name, and that was quite unfortunate because cedar is not a characteristic plant of this region. Cedar is an invader. Cedar was not naturally found in this region, at least, not in near the numbers as today. In fact, in all the early writings, no one mentioned cedar as being in this region, except in the river bottoms or on the bluffs. These two areas are where the cedar would have been protected from fire.

In 1818 Schoolcraft, when he traveled through this region, wrote the following, "The country we passed over yesterday after leaving the valley of the White River presented a character of universal sterility. Sometimes we crossed patches of ground of considerable extent without trees or brush of any kind. Frequently these prairies occupied the tops of hills or extended ridges while the intermittent valleys were covered with oaks." I believe the "patches" that they crossed were glades, and the land with the oaks in between these open patches of glades was savanna.

A lot of early writings talk about how the woods were "open." One author saying, "You can ride from Ava to Forsyth and wouldn't have to get off your horse." There was no brush, as we see today. The author continued, "You could take a wagon all the way without a road to any destination." This is the same description that some of the earlier speakers discussed.

I worked primarily with the Mark Twain National Forest on the Ava Ranger District. I went to Ava in l975. I helped get their glade and savanna restoration effort started. The Missouri Department of Conservation started their glade and savanna restoration project in about l980 in our area. Their efforts were primarily on the Caney Mountain and Drury-Mincy conservation areas. Through the years we developed a wonderful working relationship between the agencies. This relationship really helped both of our respective burn programs.

We did a range analysis on the Ava Ranger District in the early l980's. Basically, we compared aerial photos. Aerial photos from l938 were compared to aerial photos from 1975. In l938, 50% of the area had 0-15% canopy closure, where in l975, less than 20% of the area had a 0-15% canopy closure. Conversely, by l975 over 50 % of the area had 50-100% canopy closure, and in l938 only 20% of the area had 50-100% canopy closure. You can see how much the canopy closed down in that 40 year period. All the savannas were choked with sprouts and brush. Richard Guyette did a study of tree fire scars on the Ava Ranger District. He studied cedars with fire scars dating back to the early 1600's. While the Osage Indians inhabited this region they did influence fire frequency. This lasted up through the end of the 1700's. Then, the eastern tribes came in and there was an increase in the fire occurrence. After 1850, fire frequency went down. This is when settlement increased. There was some fire occurrence until the Civil War, and then it dropped off significantly. There was a little fire around l900 and around l950, enough to record.

In 1840 Monk wrote, "People gave their time for growing livestock, especially horses and cattle. A man could raise all the livestock in the way of horses and cattle that he could possibly look after. The only expense was salting and caring for them. You do not have to feed winter or summer, except for the horses in use and cattle used for milking purposes." When people did come in, they brought their livestock. It was open range with lots of hogs and cattle, particularly cattle in our region. Pretty soon that lush grass was gone. Open range stayed in our region until the 1950's.

The U. S. Forest Service was created in the late-1920's and early-1930's. This is when the Federal Government bought up the land, especially through the depression years. Until the mid-1950's, it was open range. Christian County, which is one of the four counties that make up the Ava Ranger District, did not close open range until 1962. Essentially, there was no livestock management on National Forest Land since people were running cattle on the open range throughout this region.

Uncle Sam did an effective job of saying "YOUR forest, YOUR fault, YOUR loss"...... all fire is bad. The CCC crews came in during the 1930's. On the Ava Ranger District, which is about 150,000 acres, there were 3 CCC camps. These were big camps, with well-trained fire fighting crews. They had pickup trucks and they could get to fires fairly quickly. They were well equipped to fight fire. So, fire occurrence basically stopped. As they say, "The rest is history." The brush took over. There was nothing but brush. And, this greatly affected the cattle industry.

In the early 1970's, they started doing some burning. When they first started, they used backing fires. These fires were easy to control. The problem with backing fires is that you do not cover very much area. Then in the 1980's, we started using strip fires. Basically, you burn in strips. This increased the speed in which we could burn. Then we started using ring head fires. This is where we start the burn with a backing fire so we can control it. We start on the downwind side. Then, when that is secure, we begin to fire around both flanks and ultimately encircle the burn unit. This finishes the burn with a head fire. This technique is extremely effective and efficient.

Like other burns that are dominated by fine fuels, these fires cool quickly. As intense as these fires look, properly timed they do not burn very deep into the litter layer and there is a lot of organic material remaining.

An area immediately after a burn looks pretty rough. You can see white spots where cedar trees were. It looks like every tree in there is burned up. Obviously, this is not the case. Generally, there are way too many stems per acre. The first treatment will take out many of the small stems, especially if they are cedars. If cedars get too large, say over 12-14' tall, you may need to cut them down in order to get rid of them. The fire may not be able to get close enough to the cambium layer to put enough heat on to kill the tree.

With the second burn, the savanna sites begin to open up a little bit. You will start seeing more native grass. I am always amazed by the seed bank that you hear so much about. It is amazing how many seeds are in the seed bank just waiting for an opportunity to grow. You can burn a savanna site and you will swear that there will not be anything there and then you will begin seeing native grasses and forbs growing within a couple of years.

George Dellinger with the Missouri Department of Conservation did some early research, beginning in the late 1950's, on the Caney Mountain Conservation Area. He looked at prescribed burning as a management technique to produce wildlife foods. Because of his research, he sowed the seeds, literally, to start using fire. He showed good forage and seed production for wildlife.

With burning, we found that you start seeing an increase in the numbers of many plant species, particularly the ones that are extremely palatable. These species included sensitive brier and slender lespedeza. These forage and seed producing plant species brought in various wildlife species. Burning also increased diversity within habitats and variety within the habitat structure. Habitat quality was increased. Some of the wildlife species that responded included deer and turkey, and interestingly, the collared lizard. Collared lizards need open habitats, like savanna.

Savanna management can produced cattle. Prior to the 1960's, there was no livestock management on the Ava Ranger District. This region had been open range. Beginning in the 1960's, the Forest Service began using grazing allotments. The people who had been running cattle on the open range got first choice at the grazing allotments. They had to go in and apply for their allotment. Their grazing allotments were regulated, which included limitations on stocking rates. But, they continued grazing large areas and were grazing the units season long. The grazing season usually ran from May to November, and then they would take the cattle off in the winter. In the l970's, we started doing a rotational grazing system. We went to a 4-pasture or 5-pasture rest-rotation. This is where you rest 1 pasture and rotate the cattle through the other pastures. Then, the pasture that was rested is burned the next spring. Also, the pasture that was burned the previous spring is the last pasture grazed during that season.

Here are some of the results of a study. Total forage yield on a burned area was 1,150 pounds per acre. This is not very much compared to prairie or bottomland soils. But, this is good for our thin soils. This is quite a bit more than when we were not doing any burning. Without the burning, forage production was around 600 pounds per acre. With burning, it almost doubled.

This study showed another result. Forge condition improved. The abundance of plant species that cattle like to eat doubled.

Soil conditions improved. To range people, soil condition is a measure of fodder or litter. Basically, it is whether there is cover on the ground, including either litter or plant cover. The more litter and plants you have growing, the better the soil conditions. Soil conditions improved from good to almost excellent. These are relatively condition classes that have been established by the Forest Service for range condition.

Also, wildlife numbers improved. Quail numbers increased in the savanna areas. Quail are known as the firebird, a name given to them by the Indians. As soon as a fire cools down, quail begin to use the area. This makes bird dogs popular and quail hunters happy. Without fire the savannas will not exist. There is no substitute. Nothing can take the place of fire in savanna management.